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METALLIC GLASSES CAST IN MAGNETIC FIELD

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Abstract. – Fe-Cr-B metallic glass ribbons were prepared in a magnetic field applied during the melt stage or when the ribbon part had already solidified. The Curie temperature of the alloy was modified by adding Cr to separate the effect of the field on solidification from the influence of magnetic annealing.

Introduction

If one applies an external magnetic field during melt spinning, induced magnetic anisotropy can be achieved [1, 2]. The aim of this paper is to investigate the development of this induced anisotropy in metallic glass ribbons prepared by applying the magnetic field in the puddle part of the melt spinning or immediately after ribbon solidification on the wheel.

According to [3], due to the influence of a magnetic field on rapid quenching from the melt the viscosity is increased thereby promoting the glass forming ability. The magnetic field is able to cause changes in the structure (oriented ordering) and in the distribution of alloyed elements. However, if the magnetic field is applied to the solidified ribbon while it is cooling down through the Curie temperature, in situ magnetic annealing occurs resulting in induced magnetic anisotropy.

Experimental results and discussion

Fe-Cr-B metallic glass ribbons were prepared by the melt spinning technique in a longitudinal (ML) or transversal (MT) magnetic field of 160-180 Oe produced by an appropriate ferromagnetic yoke. The magnetic field was applied either to the puddle from which the ribbon is formed (ML, MT) or 30 mm away from it (MLS, MTS) where the melt is already solidified. The composition of the alloys formed (see Tab. I) was determined by the atomic absorption method.

Magnetic investigations were performed by a Förster type magnetometer, by a vibrating sample magnetometer and by a magnetooptical hysteresigraph [4]. The domain structure was examined by back-scattered electron imaging [5].

Some of the magnetic parameters of the alloys studied are also given in table I. The differences between the magnetic states of ribbons cast in various magnetic fields can be seen in the resulting values of coercive force, $H_c$, and anisotropy energy, $K$, and their change due to annealing. ($K$ was determined as the energy required to magnetic saturation.) The as-quenched ribbons were annealed at temperature $T_{a1} = 0.85 T_c$, then in a 50 Oe longitudinal magnetic field at $T_{a2} = 0.9 T_c$. Measurements of $H_c$ and $K$ were always carried out at room temperature. In figure 1 examples are given of the dependence of these parameters on the annealing time $t_a$. In all samples an initial decrease of $H_c$ (stress relief) can be observed. For longer heat treatments at $T_{a1}$, increases in $H_c$ may be due to the occurrence of some structural inhomogeneities preceding crystallization. On continuing the heat treatment at $T_{a2}$ in a longitudinal magnetic field, $H_c$ decreases due to the development of induced easy magnetization direction. The anisotropy at first decreases in all samples due to relaxation and/or due to the removal of cast-in anisotropy. During heat treatment in a magnetic field the decrease of $K$ indicates the development of a longitudinal axis of easy magnetization.

Table I. – Parameters of alloy cast without magnetic field.

<table>
<thead>
<tr>
<th>Composition</th>
<th>$S$ [G]</th>
<th>$H_c$ [mOe]</th>
<th>$K$ [Jm$^{-1}$]</th>
<th>$T_c$ [K]</th>
<th>$T_{cr}$ [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$<em>{84.9}$Cr$</em>{2.4}$Br$_{14.9}$</td>
<td>1.200</td>
<td>130</td>
<td>80</td>
<td>537</td>
<td>630</td>
</tr>
<tr>
<td>Fe$<em>{83.6}$Cr$</em>{2.4}$Br$_{14.0}$</td>
<td>1.050</td>
<td>270</td>
<td>88</td>
<td>480</td>
<td>640</td>
</tr>
<tr>
<td>Fe$<em>{81.5}$Cr$</em>{4.5}$Br$_{14.0}$</td>
<td>0.0</td>
<td>60</td>
<td>35</td>
<td>430</td>
<td>450</td>
</tr>
</tbody>
</table>

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The quenched-in anisotropy, $K_{\text{as-qu}}$, (containing both induced anisotropy and quenched-in stresses) and the decrease of anisotropy due to annealing at $T_{\text{a1}}$ for 1 hour, $\delta K = K_{\text{as-qu}} - K(T_{\text{a1}}; 1 \text{ h})$ is given in figure 2. From $K_{\text{as-qu}}$ it can be seen that the magnetic field has no influence on the Cr$_{4.5}$ alloys – their $T_c$ is too low. $\delta K$ shows also only some relaxation. In 0.8 at % Cr a low $K$ value for MLS and a higher for MTS suggest that in this case an induced anisotropy was achieved cooling down through $T_c$.

In figure 3 typical surface hysteresis curves are given for FeCr$_{0.8}$B where only the MLS sample shows anisotropy properties. The ML hysteresis loop also differs from that of MO indicating that the magnetic field affects the structure of the melt too. The surface hysteresis curves are in agreement with the domain structures observed (see Fig. 4).

From the results of our investigations it can be concluded that the magnetic field influences both the melt and the solidified ribbon cooled through the Curie temperature but only the latter gives the required induced anisotropy.

![Fig. 2. - Anisotropy energy of the as-quenched state and the decrease of anisotropy due to 0.85 $T_c$ / 1 h annealing.](image)

![Fig. 3. - Surface hysteresis curves of samples prepared by different methods of magnetic casting.](image)

![Fig. 4. - Domain structures in FeCr$_{0.8}$B prepared by different casting methods.](image)