TEMPERATURE DEPENDENCE OF MAGNETIC ANISOTROPY IN AMORPHOUS Fe-B ALLOYS
H. Onodera, H. Yamamoto, H. Watanabe

To cite this version:
H. Onodera, H. Yamamoto, H. Watanabe. TEMPERATURE DEPENDENCE OF MAGNETIC ANISOTROPY IN AMORPHOUS Fe-B ALLOYS. Journal de Physique Colloques, 1979, 40 (C2), pp.C2-142-C2-143. <10.1051/jphyscol:1979249>. <jpa-00218647>

HAL Id: jpa-00218647
https://hal.archives-ouvertes.fr/jpa-00218647
Submitted on 1 Jan 1979

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
TEMPERATURE DEPENDENCE OF MAGNETIC ANISOTROPY IN AMORPHOUS Fe-B ALLOYS

R. Onodera, H. Yamamoto and H. Watanabe

The Research Institute for Iron, Steel and Other Metals, Tohoku Univ., Sendai, Japan

Résumé.- L'influence de la température et de la composition sur la distribution de champ hyperfin magnétique dans les alliages amorphes Fe$_{14-x}$B$_x$ (14 < $x$ < 21) a été étudiée par spectrométrie Mössbauer. L'axe d'aimantation facile est, dans le plan du ruban à la température ambiante, mais s'éloigne de ce plan à partir de 160 K. A basse température, le pic de distribution de la courbe de champ hyperfin présente une structure correspondant à des domaines dont la direction d'aimantation dépend fortement de la température.

Abstract.- The temperature dependence of the magnetic anisotropy and the composition dependence of the distribution of the magnetic hyperfine fields in amorphous Fe$_{14-x}$B$_x$ (x=14-21) alloys have been studied by the Mössbauer effect measurements. Easy axis of magnetization at room temperature is in the plane of the ribbon, while it tilts out of the plane below 160 K. At low temperatures the peak in the distribution of hyperfine field curve, as deduced from the middle line intensity, P$_2$, has a structure which shows the presence of domains whose magnetization direction is strongly temperature dependent.

1. Introduction.- Since Mössbauer spectroscopy is useful for studying the microscopic state in magnetic materials, many ferromagnetic amorphous alloys have been studied by $^{57}$Fe Mössbauer effect. Most of the studies are concerned with the distribution of hyperfine fields, and the patterns of the magnetic hyperfine field distribution obtained by computer analysis are not much different from those of crystalline disordered alloys. Chen and Hasegawa observed that the magnetization direction of an amorphous Fe$_{54}$Ni$_{46}$P$_{14}$B$_6$ sample lies in the plane of the ribbon above 240 K, and tilts out of the plane continuously with temperatures below 240 K /1/. Below 110 K, however, the magnetization direction begins to tilt back toward the ribbon plane. Similar behaviors were also observed in Fe$_{80}$P$_{10}$, Fe$_{75}$P$_{10}$C$_{15}$, Fe$_{29}$Ni$_{49}$P$_{14}$CoSi$_2$ /1/, Fe$_{85}$B$_{15}$ and Fe$_{75}$P$_{10}$C$_{15}$ /2/. Since the observations of the magnetic domain structure have shown that there exist two different types of domain i.e. a main domain and a 180° domain at room temperature /3/, /4/, one may postulate another mechanism where the total volume of domains with the magnetization direction parallel to the ribbon plane decreases through the domain wall motions and those with the magnetization direction perpendicular to the plane increases, instead of the tilting motion.

The magnetic anisotropy in amorphous Fe-B, Fe-P systems and in Fe$_{80}$P$_{17}$C$_{3}$ has been studied by torque measurements by Takahashi et al. and tilting of the magnetization out of the ribbon plane at low temperatures has been established /5/. The magnetic anisotropy in these amorphous alloys has been considered to be induced by stresses /4/, /6/, /7/ and the direction change of the magnetization axis with temperature has been considered to be caused by the thermal variation of the stresses /1/. In the present study we report the temperature dependences of the magnetic anisotropy and the composition dependence of the distribution of the magnetic hyperfine fields in amorphous Fe$_{14-x}$B$_x$ (x=14-21) alloys.

2. Experiments and Results.- The amorphous Fe-B samples were prepared by rapid quenching from the molten alloys using the single roller type quenching apparatus. The ribbons thus obtained are 1-2.5 mm in width and 20-60 μm in thickness. The amorphous state of samples were confirmed by the X-ray diffractions. The measurements of the Mössbauer effect have been performed with a conventional method in which the direction of γ-rays from the Pd ($^{57}$Co) source is perpendicular to the ribbon plane. Figure 1 shows the temperature dependence of the intensity of the middle absorption lines, which are caused by the transitions between $\frac{1}{2}$ and $\frac{3}{2}$ levels. The intensity scale is chosen so that the intensity of the outermost lines ($\frac{3}{2} - \frac{1}{2}$) is set equal to 3. With this scale, the intensity 4 corresponds to the magnetization direction being parallel to the ribbon plane, while 2 corresponds to a random distribution of the magnetization direction. Similar temperature dependence of the middle absorption lines has been reported /1/, /2/ as stated in the introduction. As can been seen from the figure the intensities of the middle lines are less than 4 at room temperature, and the increase of the intensity is not always ob-
served below 110 K for all the samples. The Mössbauer spectra have been analyzed with the computer by a modified Hesse-Rübertsch's method /8/ in which the distribution of hyperfine fields appeared in 

\( (\pm \frac{3}{2} - \pm \frac{1}{2}) \) and 

\( (\pm \frac{3}{2} - \pm \frac{1}{2}) \) absorption lines (P1,3) and that in the 

\( (\pm \frac{3}{2} - \pm \frac{1}{2}) \) lines (P2) can be obtained separately.

P1,3 and P2 are shown in figure 2 where both distribution curves are normalized by 

\[ \int_{0}^{\infty} \text{H} \text{dH} = 1 \]

in order to make comparison easier.

3. Discussion.- The intensity ratio of the six lines in the \(^{57}\text{Fe} \) Mössbauer spectrum is given by 

\[ 3f(\theta):1:1:f(\theta):3 \]

where 

\[ f(\theta) = 4\sin^2\theta/(1+\cos^2\theta) \]

and 

\( \theta \) is the angle between the directions of \( \gamma \)-rays and of the hyperfine field at \(^{57}\text{Fe} \) nuclei. Hence the information emphasized about the hyperfine fields nearly parallel to the ribbon plane is included in P2. P2 obtained from the spectra at room temperature where the magnetization directions are nearly parallel to the plane has a similar shape to that of P1,3. However, the shapes of P2 are different from those of P1,3 at 20 K as shown in figure 2, having a certain structure in the line profile. The shape of P2 are depressed roughly in the middle position of the peak as compared with those of P1,3. This would mean that \(^{57}\text{Fe} \) atoms which have the hyperfine fields close to the mean value have their spin direction much tilted away from the ribbon plane. If we simply assume that the width of the peak in P(H) curve comes from the compositional fluctuation, the above result may be stated as the substance is made up of two types of domains, one having the B content close to the nominal composition and the spin directions tilted out of the ribbon plane, while the other having the B content deviated from the nominal composition and the spin directions in the ribbon plane. The mechanism leading to this result is considered to be the internal stress caused by the fluctuation in the composition.

References