



HAL
open science

THE MAGNETOSTRICTION AND MAGNETIC BEHAVIOUR OF AMORPHOUS (Fe_{80-x}R_x) B₂₀ (R = Y, Ce, Nd, Sm, Gd, Dy, Ho, Er, Tm Lu) (0 < x < 10)

R. Grössinger, H. Sassik, R. Wezulek, T. Tarnoczi

► **To cite this version:**

R. Grössinger, H. Sassik, R. Wezulek, T. Tarnoczi. THE MAGNETOSTRICTION AND MAGNETIC BEHAVIOUR OF AMORPHOUS (Fe_{80-x}R_x) B₂₀ (R = Y, Ce, Nd, Sm, Gd, Dy, Ho, Er, Tm Lu) (0 < x < 10). Journal de Physique Colloques, 1988, 49 (C8), pp.C8-1337-C8-1338. <10.1051/jphyscol:19888611>. <jpa-00228836>

HAL Id: jpa-00228836

<https://hal.science/jpa-00228836v1>

Submitted on 4 Feb 2008

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.



HAL Authorization

THE MAGNETOSTRICTION AND MAGNETIC BEHAVIOUR OF AMORPHOUS $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($\text{R} = \text{Y}, \text{Ce}, \text{Nd}, \text{Sm}, \text{Gd}, \text{Dy}, \text{Ho}, \text{Er}, \text{Tm}, \text{Lu}$) ($0 < x < 10$)

R. Grössinger ⁽¹⁾, H. Sassik ⁽¹⁾, R. Wezulek and T. Tarnoczi ⁽²⁾

⁽¹⁾ *Inst. f. Experimentalphysik, Techn. Univ. Vienna, Austria*

⁽²⁾ *KFKI Budapest, Hungary*

Abstract. - Amorphous ribbons of the composition $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($\text{R} = \text{Y}, \text{Ce}, \text{Nd}, \text{Sm}, \text{Gd}, \text{Dy}, \text{Ho}, \text{Er}, \text{Tm}, \text{Lu}$) ($0 < x < 10$) were produced. The behaviour of the saturation magnetisation can be explained assuming an asperomagnetic type of order. The magnetostriction decreases with increasing R-concentration for all rare earth elements studied here.

Introduction

$\text{Fe}_{80}\text{B}_{20}$ is a well known soft magnetic amorphous material with a high saturation induction ($I_s = 1.6 \text{ T}$) and an unusual high positive magnetostriction ($\lambda_s = +34 \times 10^{-6}$). A small ("zero") magnetostriction causes a low coercivity in soft magnetic materials. The systems $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($\text{R} = \text{Y}, \text{Ce}, \text{Nd}, \text{Sm}, \text{Gd}, \text{Dy}, \text{Ho}, \text{Er}, \text{Tm}, \text{Lu}$) ($0 < x < 10$) were investigated in order to study how the rare earth element substitution influence the magnetostriction.

Rare earth elements exhibit generally large magnetostrictive effects because of their orbital moment. It is therefore a hope that a small amount of a rare earth substitution is sufficient to obtain a compound with zero magnetostriction.

Experimental

A set of ribbons of the composition $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($0 < x < 10$) was produced by the single roller technique under He atmosphere ($p = 500 \text{ mbar}$). The amorphous state of the ribbons was tested by X-rays but also by optical microscopy. No evidence of crystalline inclusions was detected.

The hysteresis loop was measured at room temperature using a hysteresograph as published by O'Dell [1]. This hysteresograph produces external fields up to $1\,200 \text{ A/m}$. This field is not sufficient to saturate the samples. The saturation of some selected ribbons was therefore determined using a Faraday balance in an external field of 48 kA/m . The saturation value as determined at a field of 400 kA/m was within the experimental error the same.

Due to the geometry of amorphous ribbons (length \gg width \gg thickness) "special" techniques for determining the magnetostriction were developed (see e.g. 2, 3). Nearly all of them are based on the stress dependence of magnetic properties (like the coercivity or the susceptibility etc.). The most sensitive method is the SAMR (Small Angle Magnetization Rotation Method) as described by [4], which was applied here. With this technique λ_s can be determined down to 10^{-8} .

Results and discussion

The concentration dependence of the saturation magnetization for $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ is shown in figure 1 for $\text{R} = \text{Ce}, \text{Nd}, \text{Sm}, \text{Gd}$, and in figure 2 for $\text{R} = \text{Dy}, \text{Ho}, \text{Er}, \text{Tm}$. In both cases M_s decreases with the con-

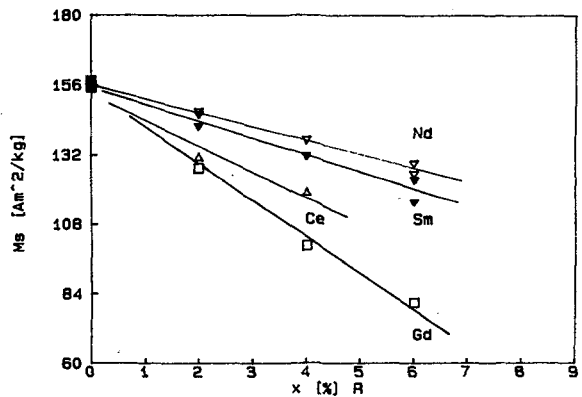


Fig. 1. - Saturation magnetization as a function of x of the ribbons with the composition $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($\text{R} = \text{Ce}, \text{Nd}, \text{Sm}, \text{Gd}$) as determined at room temperature.

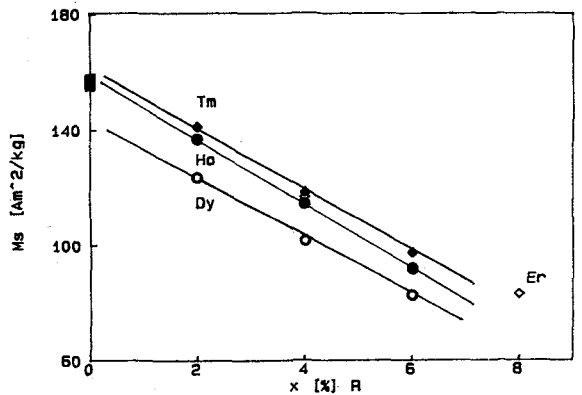


Fig. 2. - Saturation magnetization as a function of x of the ribbons with the composition $(\text{Fe}_{80-x}\text{R}_x)\text{B}_{20}$ ($\text{R} = \text{Dy}, \text{Ho}, \text{Er}, \text{Tm}$) as determined at room temperature.

centration x . This is surprising if one assumes that the magnetic moment of the light rare earth elements (LR) couples parallel to that of the Fe and the moment of the heavy rare earth elements (HR) couples antiparallel to the Fe moment, as usual in such compounds, if they are crystalline.

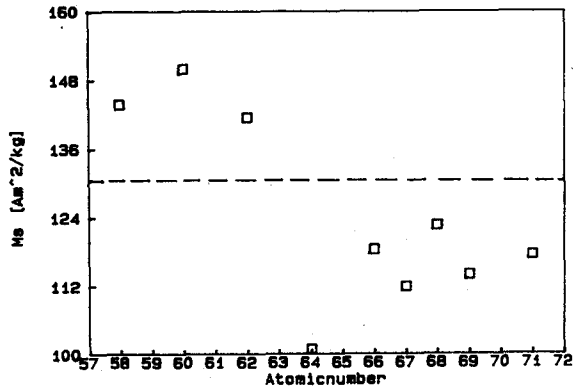


Fig. 3. - Saturation magnetization of $\text{Fe}_{74}\text{R}_6\text{B}_{20}$ as a function of the atomic number of the lanthanides. Note the dotted line of the corresponding mean value of the Y- and Lu-compound, which is usual as a reference.

Figure 3 shows the magnetization of $\text{Fe}_{74}\text{R}_6\text{B}_{20}$ versus the atomic number of the lanthanides taking the mean value of the magnetization of the corresponding compounds containing a nonmagnetic R-element ($\text{Fe}_{74}\text{Lu}_6\text{B}_{20}$ and $\text{Fe}_{74}\text{Y}_6\text{B}_{20}$) as a reference line. This picture demonstrates that the light rare earths (LE) couple with a ferromagnetic component whereas the heavy rare earth moments (HR) couple with a ferrimagnetic component to the Fe-moment. However the situation is not simple. The rather low magnetization values and in particular the reduction of M_s in the case of the light rare earth indicate a noncollinear arrangement of the moments as was found for similar systems [5]. It is worth to note that the slope dM_s/dx is approximately $-6 \text{ Am}^2/\text{kg}/\text{at}\%$ (at% ... atomic percent) for all light rare earth elements but $-10 \text{ Am}^2/\text{kg}/\text{at}\%$ for all heavy rare earths indicating a different arrangement of the magnetic moments. In all cases the ordering temperature decreases with increasing R concentration, indicating a reduced exchange. These results can be explained assuming a fan structure which is generally called asperomagnetism or sperimagnetism if antiparallel coupling is involved. The magnetostriction also decreases linearly with increasing amount of rare earth. Plotting the value λ_s but also the slope $d\lambda_s/dx$ versus the rare earths gave no clear trend, which might be also a consequence of the complex type of order. In table I the data for λ_s , as obtained at room temperature, are given.

Table I. - Magnetostriction constants $\lambda_s \times 10^{-6}$ as obtained for $\text{Fe}_{80-x}\text{R}_x\text{B}_{20}$ at room temperature.

| x | R = Ce | Nd | Sm | Gd | Dy | Ho | Er | Lu |
|-----|--------|------|------|------|------|------|------|------|
| 2 | 28.9 | 27.5 | 28.8 | 29.3 | 28.0 | 27.9 | - | - |
| 4 | 23.0 | 21.8 | 24.0 | 23.3 | 20.8 | 20.5 | 25.0 | 21.5 |
| 6 | - | 13.0 | 19.1 | 18.5 | 13.8 | 13.3 | 19.7 | 14.7 |

The temperature dependence of the magnetostriction in such amorphous ribbons can be explained assuming a single ion (scaling with M_s^3) as well as a two ion contribution (scaling with M_s^2) [6]. Due to the asperomagnetic type of order no simple scaling between λ_s and a certain power of M_s can be expected. The coercivity of the ribbons in- or decreases depending on the rare earth element acting as a substituent. In a simple model H_c should scale with λ_s in soft magnetic materials. In our case $H_c(x)$ could not be correlated with the concentration dependence of the magnetostriction. Metallurgical parameters especially intrinsic stress centers may determine H_c also. A better insight about the origin of the magnetostriction as well as about any correlation between λ_s and the coercivity is possible if temperature dependent studies are available. Additionally the type of magnetic order in the rare earth substituted ribbons is still open. For this purpose additional experiments like Mossbauer, high field magnetization and temperature dependent magnetization studies are in progress.

Acknowledgement

This work was supported by the Austrian "Fond zur Förderung der wissenschaftlichen Forschung in Österreich" Projekt Nr. 5020.

- [1] O'Dell, T. H., *IEEE Trans. Magn. MAG-17* (1981) 3364.
- [2] O'Dell, T. H., *Phys. Status Solidi A* **68** (1981) 221.
- [3] Hilzinger, H. R., Hillmann, H., Mager, A., *Phys. Status Solidi A* **55** (1979) 763.
- [4] Narita, K., Yamasaki, J., Fukunaga, H., *IEEE Trans. Magn. MAG-16* (1980) 435.
- [5] Ryan, D. H., Liao, L. X., Altounian, Z., *Solid State Commun.* **66** (1988) 339.
- [6] Madurga, V., Vazques, M., Hernando, A., Nielsen, O. V., *Solid State Commun.* **52** (1984) 701.