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MÖSSBAUER INVESTIGATION
OF THE MAGNETIC ANISOTROPY AND
ELECTRONIC STRUCTURE OF A METALLIC GLASS

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ABSTRACT

The magnetic anisotropy of a $\text{Fe}_{80}\text{B}_{20}$ /METGLAS 2605/ metallic glass has been investigated by Mössbauer spectroscopy. The direction of magnetization is shown to be strongly temperature dependent with an unusually large out-of-plane component. The similarities between the electronic structure of this glassy alloy and the Fe_2B and FeB intermetallic compounds are discussed briefly.

АННОТАЦИЯ

С помощью эффекта Мессбауэра изучалась магнитная анизотропия аморфного сплава $\text{Fe}_{80}\text{B}_{20}$ /METGLAS 2605/. Обнаружено, что направления легкого намагничивания сильно зависят от температуры. Получено также необходимо большое значение перпендикулярной составляющей намагничивания по отношению к поверхности фольги. Кратко излагается сходство электронной структуры аморфного сплава $\text{Fe}_{80}\text{B}_{20}$ и интерметаллического соединения Fe_2B и FeB.

KIVONAT

Mössbauer spektroszkópia segítségével vizsgáltuk a $\text{Fe}_{80}\text{B}_{20}$ /METGLAS 2605/ fémüveg mágneses anizotrópiáját. Megmutattuk, hogy a könnyű mágnesezési irány erősen hőmérsékletfüggő és a fólia síkjára merőleges komponens szokatlanul nagy. Röviden taglaljuk e fémüveg és a Fe_2B és FeB intermetallikus vegyületek elektronszerkezete közötti hasonlóságot.

Since the intensity ratio of the six lines in a Fe^{57} Mössbauer spectrum depends on the direction of magnetization with respect to the γ -ray direction, Mössbauer effect can be used for studying the magnetic anisotropy and domain structure of metallic glasses. The first result of this type was obtained by Tsuei, Longworth and Lin [1], who found that the easy direction of magnetization of an as-quenched $\text{Fe}_{80}\text{P}_{12.5}\text{C}_{7.5}$ glassy alloy lied in the ribbon-plane /the intensity ratio being 3:4:1:1:4:3/ but after annealing the intensity ratio became 3:2:1:1:2:3, indicating a random orientation of magnetic domains. More recently Chien and Hasegawa observed that the magnetization direction of a $\text{Fe}_{40}\text{Ni}_{40}\text{P}_{14}\text{B}_6$ /Allied Chemical METGLAS 2826/ metallic glass sample was strongly dependent on the temperature between 240°K and 77°K first tilting out of the ribbon plane with a maximum angle of about 45° at 110°K and tilting back towards the ribbon plane below 110°K [2].

This paper deals with a similar example for the temperature dependence of the average magnetization direction in an $\text{Fe}_{80}\text{B}_{20}$ /Allied Chemical METGLAS 2605/ glassy alloy, but with a much more pronounced out-of-plane component. In the second part of the paper the similarities between the properties of this metallic glass and the Fe_2B and FeB intermetallic compounds are discussed.

Mössbauer spectra of a glassy $\text{Fe}_{80}\text{B}_{20}$ sample were recorded between 77°K and 363°K using a conventional constant-acceleration Mössbauer spectrometer with a 10 mCi Co^{57} in Pd source. The data were collected in a 1024-channel analyser. In Fig. 1 some typical Mössbauer spectra are presented. Since our aim was only to study the intensity ratio of the peaks and the average hyperfine field and isomer shift, the spectra were fitted to six Lorentzian lines with different widths for the three pairs of lines. This evaluation involves the presumption that the hyperfine field distribution has a Lorentzian shape. Of course, this is not the case. The intensity ratio of the outer and inner peaks was found to be about 3:0.75, indicating that the overlapping between the neighbouring lines may cause systematical errors in the line-intensities. For this reason the obtained results can only be regarded as semi-quantitative ones. When allowing the widths of the three pairs of lines to vary independently, the width of the outer peaks increased and that of the

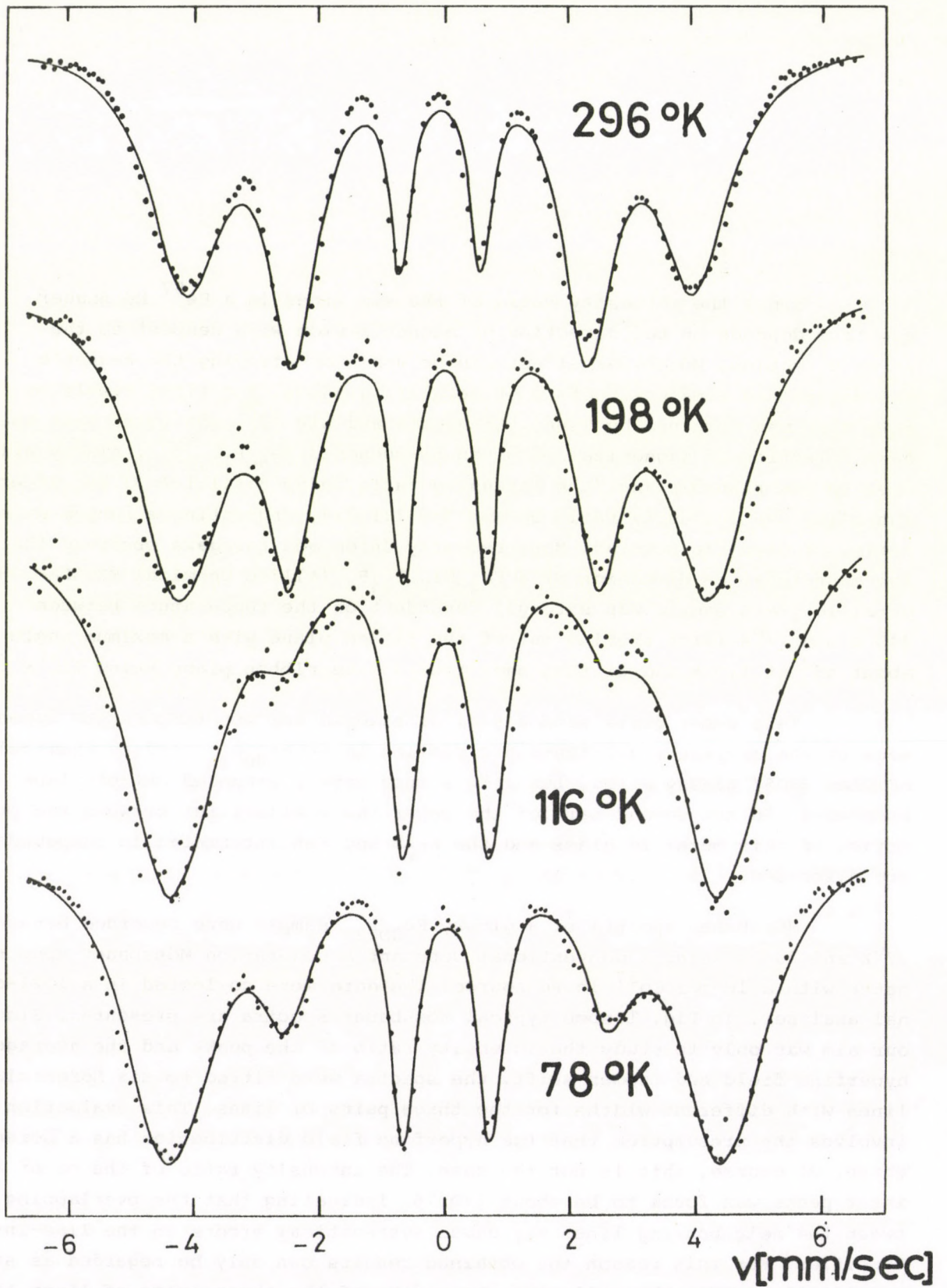


Fig. 1 Typical Mössbauer spectra of an $Fe_{80}B_{20}$ /METGLAS 2605/ metallic glass

second and fifth lines decreased with the decrease of the intensity of the second and fifth lines. To avoid this apparent change, we fixed the ratio of the line-widths to its room temperature value.

In Fig. 2 the intensity of the second and fifth lines - normalised to the one-third of the outer line intensity - is presented as a function of temperature. This variation could be interpreted as a change in the 'average tilt angle' of the magnetization direction [2] between about 30° and 65° . It is thought, however, that a more realistic interpretation can be given assuming that there are magnetic domains with magnetization direction lying in the ribbon plane and perpendicular to the ribbon plane and determining the ratio of the volume of the two types of domains. The right-hand scale in Fig. 2 indicates this ratio.

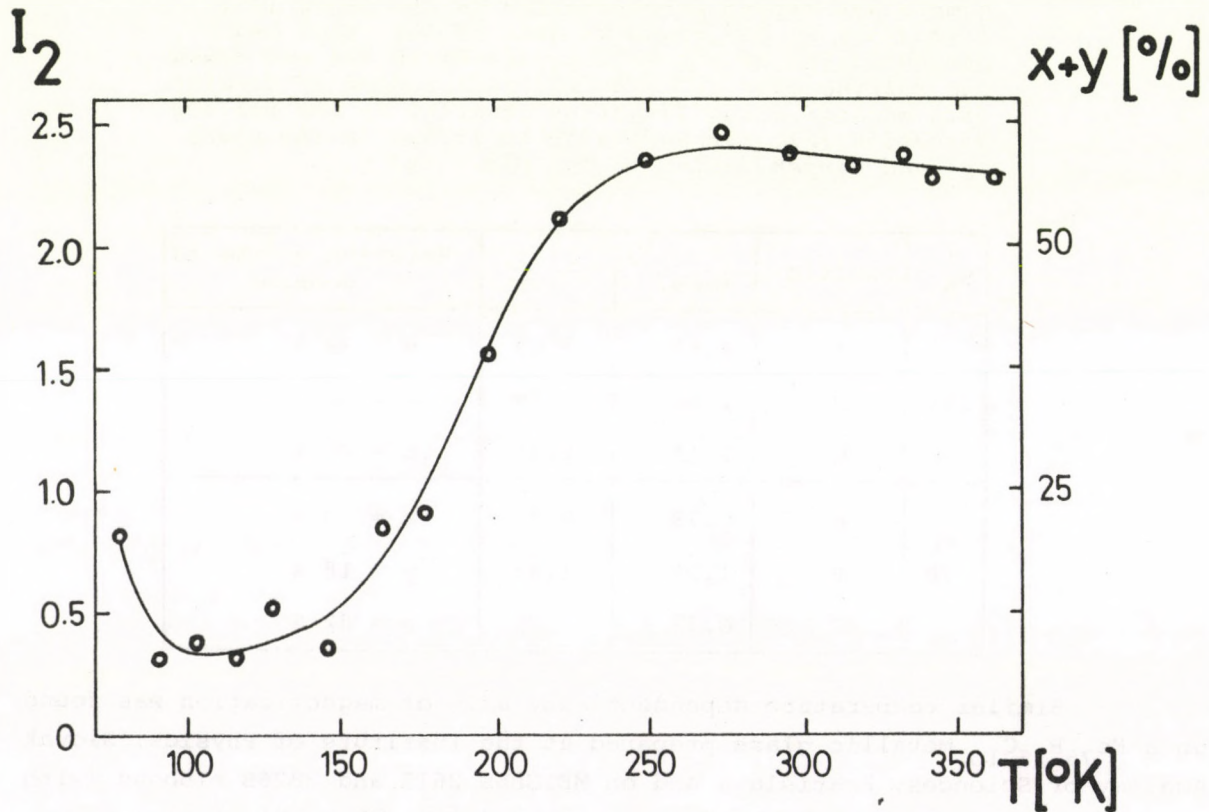


Fig. 2 The relative intensity of the second peak and the relative volume of in-plane-anisotropy domains as a function of temperature

To control this interpretation the sample was turned out from its perpendicular-to-the- γ -ray direction with an angle of 35° round the rolling direction and round an axis perpendicular to it but lying in the ribbon plane and Mössbauer spectra were taken in such geometries at liquid nitrogen and

room temperature. The measured intensities of the second and fifth lines are collected in Table I. These measurements enabled to estimate the relative volumes of domains with magnetization direction parallel to the rolling direction /x/, in the plane but perpendicular to the rolling axis /y/ and perpendicular to the ribbon plane /z/ /Table I/. The results show that the probability of domains with magnetization in the y direction is rather low and nearly temperature-independent, and on decreasing the temperature the direction of magnetization in a number of domains changes from the rolling direction to perpendicular to the ribbon plane, probably because of the change in magnetostriction. These results would be worth comparing with direct domain structure investigations and temperature-dependent magnetostriction measurements.

Table I Intensity of the second peak I_2 in three different sample positions: perpendicular to the γ -ray (A), tilted out by 35° round an axis in the plane and perpendicular to the rolling direction (B) and round the rolling axis (C). The relative volume of domains with magnetization direction parallel to the rolling direction (x), perpendicular to it but in the plane (y) and perpendicular to the plane (z)

T $^{\circ}\text{K}$	Position	I_2		Relative volume of domains
		meas.	est.	
296	A	2.37	2.22	x = 39 %
	B	1.66	1.79	y = 16 %
	C	2.11	2.25	z = 45 %
78	A	0.79	0.73	x = 0 %
	B	1.55	1.37	y = 18 %
	C	0.77	1.01	z = 82 %

Similar temperature dependent easy axis of magnetization was found on a $\text{Fe}_{75}\text{P}_{15}\text{C}_{10}$ metallic glass prepared at the Institute of Physics, Slovak Academy of Sciences, Bratislava and on METGLAS 2615 and 2826B ribbons /with compositions $\text{Fe}_{80}\text{P}_{16}\text{B}_1\text{C}_3$ and $\text{Fe}_{29}\text{Ni}_{49}\text{P}_{14}\text{B}_6\text{Si}_2$ / [2]. Thus this temperature dependent magnetization direction may be a general feature of metallic glasses prepared by 'mill devices'.

As it is expected for metallic glasses, the $T^{3/2}$ law of the temperature dependence of the hyperfine field is valid up to a rather high temperature /Fig. 3/, large deviations occur above room temperature only. The average hyperfine field extrapolated to 0°K is 276 ± 2 kOe. The width of the hyperfine field distribution is about 75 kOe estimated from the line-widths.

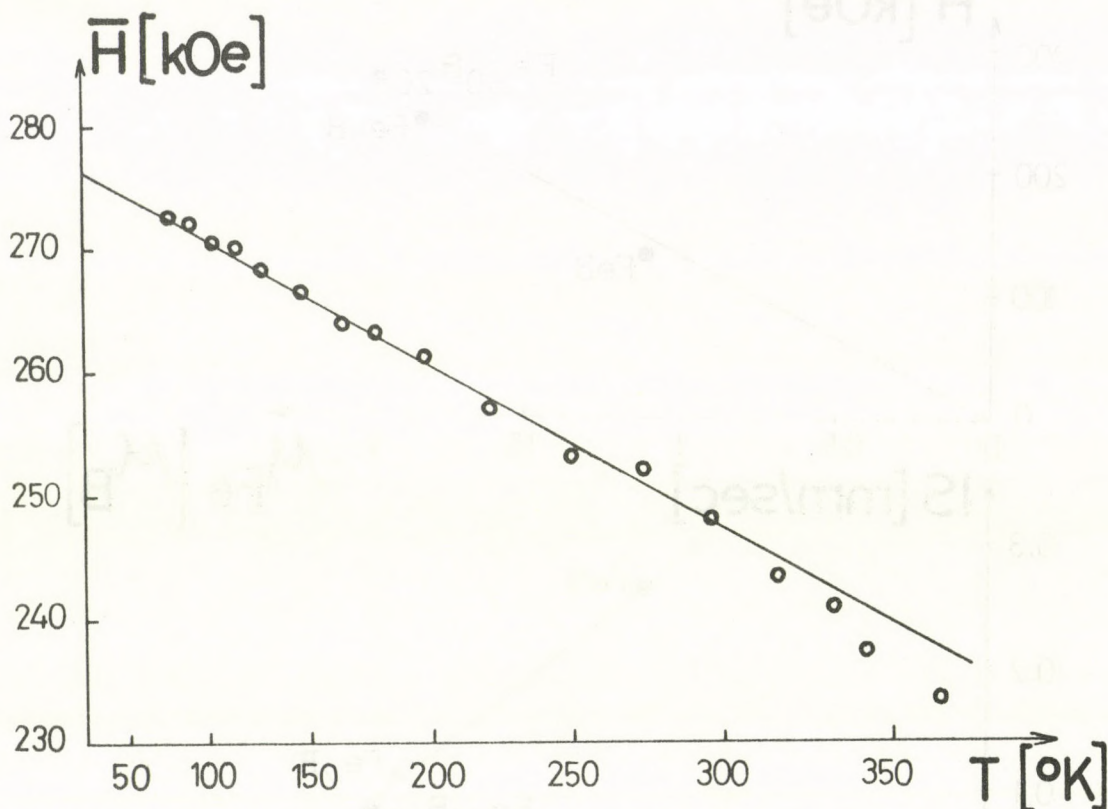


Fig. 3 $T^{3/2}$ dependence of the average hyperfine field

In metallic iron the hyperfine field is the sum of the core polarization and conduction electron polarization contributions [3]. It has been shown, however, that in the Fe_2B and FeB /and some other/ intermetallic compounds the 3d electrons are much more localised and the conduction electron polarization can be neglected [4]. The ratio of the hyperfine field and the magnetic moment in the investigated $\text{Fe}_{80}\text{B}_{20}$ metallic glass [5] is the same as that in the intermetallic compounds mentioned /Fig. 4/. Thus we expect that the decrease in the metalloid content which is necessary to the formation of the glassy state, is compensated by the structural randomness of the glass. This random arrangement of atoms will enhance the localisation of the electronic states, allowing the magnetic moment in the glassy alloy to be almost as localised as in an intermetallic compound.

The magnetic moment of these intermetallic compounds and metallic glasses is generally explained in terms of the donor model. In this model the interaction between the transition metal and metalloid results in an electron transfer from the metalloid to the metal 3d band. In accordance with this model the isomer shift is a linear function of the magnetic moment [4]. This systematics will also hold for this metallic glass. Although the precise in-

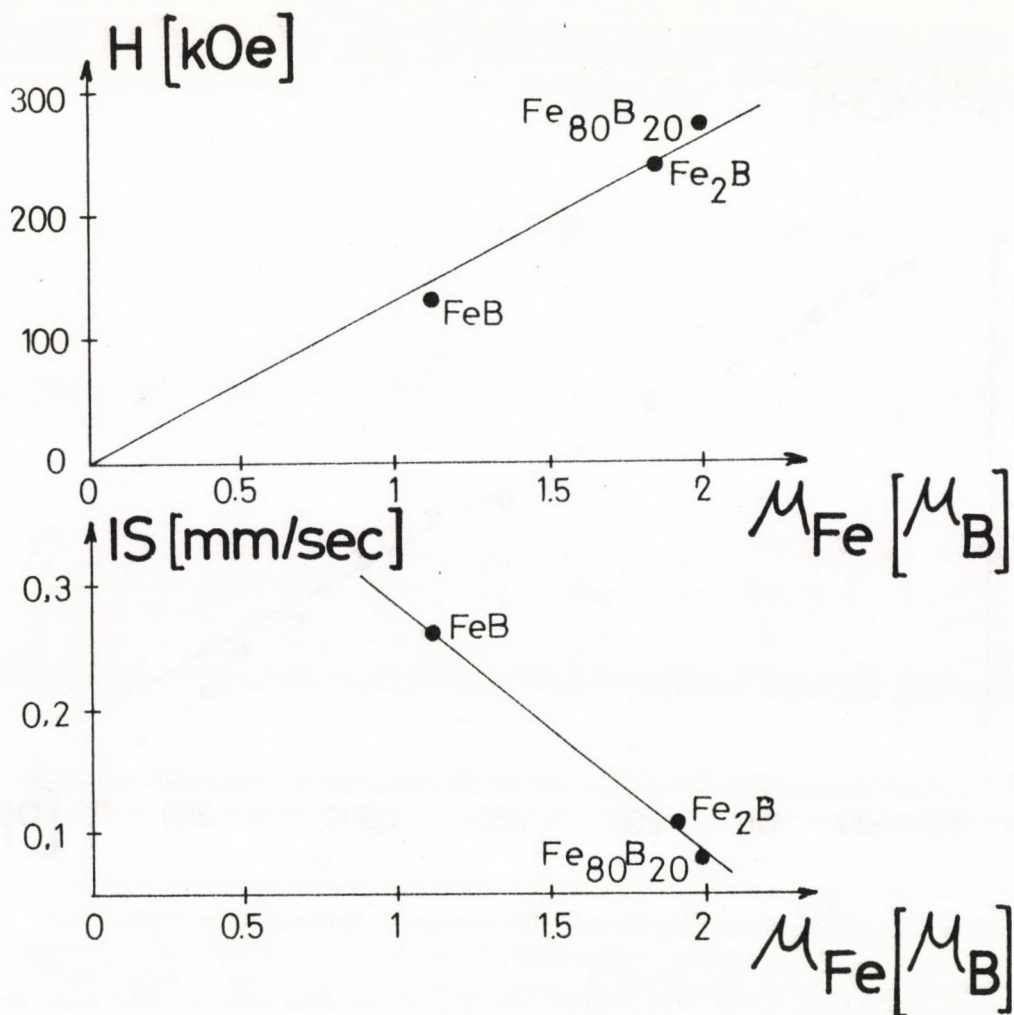


Fig. 4 Correlation between the magnetic moment /extrapolated to 0°K/ and hyperfine field /extrapolated to 0°K/ and isomer shift /at room temperature, relative to α -iron/ for Fe₂B and FeB crystalline compounds and Fe₈₀B₂₀ metallic glass

terpretation of the isomer shift in metallic systems is questionable, the fact that its behaviour in this glassy alloy is the same as in the crystalline intermetallic compounds with similar constituents shows that the structural randomness does not effect substantially the local properties and the character of the chemical bond.

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