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MAGNETIC PHASE TRANSITION OF AMORPHOUS ALLOYS FeNiSiB

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Static and dynamical behaviour of amorphous ferromagnets FeNiSiB was investigated by the Mössbauer spectroscopy and magnetostatic methods below and above T_C . The distributions of hyperfine magnetic field in the ferromagnetic phase and quadrupole splitting in the paramagnetic one were extracted by means of the constrained Hesse-Rübarth method. The static critical exponents were determined using the power laws and the Kouvel-Fisher method. The results of the Mössbauer investigations were compared with those obtained by magnetic measurements.

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1. Introduction

With the aim of studies of the magnetic phase transition in amorphous FeNiSiB ferromagnets two complementary experimental technics were used: the Mössbauer spectroscopy and bulk magnetization measurements by use of a magnetic balance.

The first, microscopic method is sensitive to local fluctuations of the hyperfine parameters: hyperfine magnetic field, quadrupole splitting and isomer shift. Static critical exponent β is related to the average hyperfine magnetic field. The dynamical effects can be also observed.

The second method is macroscopic in this sense that it allows to measure average magnetic moment. It needs presence of external magnetic field, then the static critical exponents β , γ , δ have to be determined by analyzing of magnetic equation of state.

2. Experimental

Amorphous ferromagnetic alloys FeNiSiB in form of ribbons with thickness about 30 μm , prepared by the conventional melt spinning method were investigated. Most of them were produced at the Institute of Materials Science and Engineering (Technical University of Warsaw).

The series of the Mössbauer measurements were performed in the temperature range 300–750 K. The conventional transmission geometry and the absorber

technic were used and the temperature stability over 24 h (controlled by computer) was better than 0.15 K.

The magnetization M was measured as a function of temperature and external magnetic field, in the range $500 \text{ Oe} \leq H_{\text{ext}} \leq 11 \text{ kOe}$.

3. Critical behaviour from the Mössbauer studies

A review of the more common, model independent methods to obtain hyperfine parameter distributions $P(x)$ in the Mössbauer effect spectroscopy has recently been published [1, 2]. During studies of amorphous FeNiSiB ferromagnets [3–6] we have used as well the matrix method [7, 8] as the expansion of $P(x)$ over a function set [9–11]. But not all the methods are convenient in the critical region. That is just why we have recently followed the Hesse–Rübartch method [7, 8]. In our case the hyperfine parameter x is the local hyperfine magnetic field or the quadrupole splitting. We present here only some important results related to the magnetic phase transition.

In these amorphous alloys the continuous, well-defined critical point occurs. Assuming that below the Curie temperature T_C the local magnetic hyperfine field is proportional to the local magnetization, the temperature dependence of the effective exponent β_{eff} and the ratio of the width of hyperfine field distribution to the average hyperfine field $\Delta H/H_{\text{mean}}$ were analyzed. The variation of the effective exponent β_{eff} shown in Fig. 1 is in agreement with other experimental data and theory [12]. The quantity $\Delta H/H_{\text{mean}}$ slightly increases with increasing

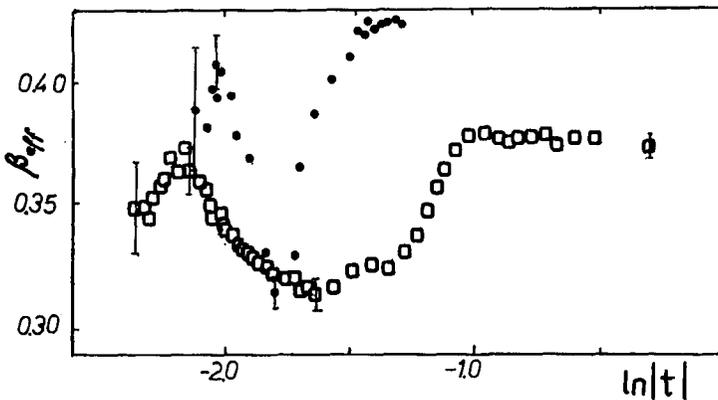


Fig. 1. Effective exponent β_{eff} obtained from the Mössbauer spectroscopy: \square $\text{Fe}_{35}\text{Ni}_{40}\text{Si}_{10}\text{B}_{15}$, \circ $\text{Fe}_{45}\text{Ni}_{30}\text{Si}_{10}\text{B}_{15}$.

temperature and reaches a maximum just below T_C [4, 5] as it was predicted by Fähnle and Herzer [13], by means of the self-consistent correlated molecular field theory developed for disordered systems.

The Mössbauer line broadening just above T_C was observed, which could be interpreted as a critical effect [13].

4. Critical behaviour from magnetic measurements

To derive the zero-field properties like spontaneous magnetization M_s and initial susceptibility χ_0 the modified asymptotic analysis method AAI [12] was used. This method is based on the magnetic equation of state:

$$(H/M)^{1/\gamma} = at + bM^{1/\beta} \quad (1)$$

which is postulated to be valid in the asymptotic critical region. Here $t = (T - T_C)/T_C$ is the reduced temperature and H is the internal magnetic field ($H = H_{\text{ext}} - H_d$, H_d — demagnetization field). We make use of the iteration procedure, starting with $\beta = 0.4$ and $\gamma = 1.4$ and computing values of M_s , χ_0 from the intercepts of the parallel straight-line isotherms in modified Arrot-Noakes plot ($M^{1/\beta}$ vs. $(H/M)^{1/\gamma}$). The values of exponents β and γ were derived by the Kouvel-Fisher method based on the relations

$$X(T) = \chi_0^{-1} (d\chi_0^{-1}/dT)^{-1} = (T - T_C)/\gamma,$$

$$Y(T) = M_s (dM_s/dT)^{-1} = (T_C - T)/\beta, \quad (2)$$

with fitting parameters β , γ , T_C , as illustrated by Fig. 2. The exponent δ was

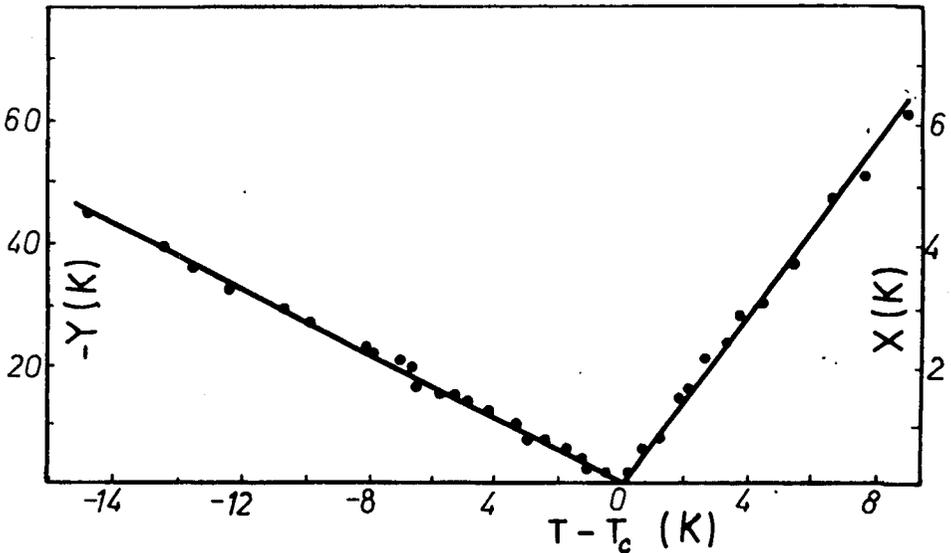


Fig. 2. Determination of T_C and critical exponents β , γ by the Kouvel-Fisher method ($\text{Fe}_{35}\text{Ni}_{40}\text{Si}_{10}\text{B}_{15}$).

determined from the slope of the isotherms $M(H)$ in the critical region. The results of exponents β , γ , δ and δ_0 , α_0 computing from the scaling relations are reported in Table I.

TABLE I

Critical exponents obtained from magnetic measurements.

	β	γ	δ	δ_0	α_0
Fe ₃₅ Ni ₄₀ Si ₁₀ B ₁₅	0.353(15)	1.47(4)	5.20(10)	5.26(25)	-0.18(7)
Fe ₄₀ Ni ₃₅ Si ₁₀ B ₁₅	0.354(15)	1.45(4)	5.16(10)	5.23(25)	-0.16(7)
Fe ₄₅ Ni ₃₀ Si ₁₀ B ₁₅	0.40(2)	1.48(5)	4.90(20)	4.70(40)	-0.28(9)
Fe ₄₀ Ni ₄₀ Si ₁₃ B ₇	0.358(15)	1.50(4)	5.30(10)	5.19(25)	-0.21(7)

5. Conclusions

Compliance of results obtained by the Mössbauer spectroscopy and those derived from magnetic measurements (Table II) implies that a linear relationship between the average hyperfine magnetic field and the magnetization is fulfilled in the critical region.

TABLE II

The results obtained by the Mössbauer spectroscopy and from bulk magnetization measurements (A_0 and A are order parameter at room temperature and its critical amplitude).

	A		A/A_0		β	
	MS [kGs]	BM [emu/g]	MS	BM	MS	BM
Fe ₄₀ Ni ₄₀ Si ₁₃ B ₇	275	102	1.40	1.41	0.370	0.358
Fe ₃₅ Ni ₄₀ Si ₁₀ B ₁₅	285	100	1.43	1.35	0.355	0.353
Fe ₄₀ Ni ₄₀ Si ₁₀ B ₁₅	-	117	-	1.25	-	0.354
Fe ₄₅ Ni ₃₀ Si ₁₀ B ₁₅	360	130	1.20	1.24	0.395	0.40

The Mössbauer spectra analysis demonstrates that the sharpness of the magnetic phase transition in FeNiSiB amorphous ferromagnets is not affected by the quenched disorder. The values of the static critical exponents are close to the homogeneous three-dimensional model and satisfy the scaling relations, in conformity with the Harris criterion and the predictions of the renormalization group calculations [12, 14]. This suggests the dominant role of the exchange interactions in the critical region.

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