acta phys. slov. 38 (1988), No. 2

INFLUENCE OF MECHANICAL TENSION OF THE FMR SIGNAL IN THE AMORPHOUS ALLOY FeNiSiB

JAKAL, K.,[1] BRNUŠÁK, S.,[1] KOŠICE

The influence of the tensile tension σ on the ferromagnetic resonance signal in the X band ($f = 9.65$ GHz) of an amorphous FeNiSiB ribbon has been investigated at room temperature. Two absorption maxima were observed. Absorption in a low magnetic field was not tension dependent. The saturation magnetostriction coefficient λ_s was estimated from the second absorption maximum which depends on tension.

I. INTRODUCTION

The method of the sample preparation which influences its anisotropy is one of the factors determining the behaviour of the sample at the ferromagnetic resonance. It is generally known that also amorphous ferromagnetic materials prepared by a rapid quenching exhibit anisotropy, which could be lowered by annealing at temperatures below the Curie point [1]. The anisotropy field H_A may be expressed by means of an anisotropy coefficient K [2]. The contribution of the anisotropy field to the resonance condition of the sample is described by the expression $\mu_0 H_A$.

An increase of the applied magnetic fied intensity H_0 causes a change of geometrical dimensions of the ferromagnetic material. This magnetostriction is characterized by the λ coefficient. We suppose in accordance with [3] that the magnetostriction of an amorphous ferromagnetic sample is isotropic. There is also an inverse effect — an applied mechanical tension causes an additional field in the sample. The volume density of the magnetoelastic energy F_σ could be expressed according to [4] in the following way:

$$F_\sigma = -\frac{3}{2}\lambda\sigma\cos^2\Phi,$$

where Φ is the angle between the direction of the acting tension and the vector

---

[1] Department of Physics, Technical University, Komenského park 2, 041 20 KOŠICE, Czechoslovakia

of magnetic polarization. In the case of high tensions $\Phi \doteq 0$, which means that an additional expression

$$B_\sigma = \mu_0 \frac{3}{2} \frac{\lambda\sigma}{J_s}$$

must be included in the effective field under the general resonance condition. Here J_s is the magnetic polarization in the state of saturation and μ_0 is the permeability of the vacuum.

Thus including both mentioned contributions the resonance equation for the thin ribbon magnetized in its length direction will have the form

$$\frac{\omega_0}{\gamma} = \mu_0 H_0 + \frac{1}{2}(J_s - \mu_0 H_A) + \mu_0 \frac{3\lambda\sigma}{2J_s}, \qquad (1)$$

where the symbols ω_0 and γ have their usual meaning. With varying tension σ the change of the resonance field $\mu_0 H_0$ occurs as it follows from eq. (1). According to eq. (1) the difference between the two resonance fields, corresponding to the different tensions σ_1 and σ_2, may be written as:

$$B_{02} - B_{01} = -\mu_0 \frac{3\lambda}{2J_s}(\sigma_2 - \sigma_1) \qquad (2)$$

where $B_0 = \mu_0 H_0$. The dependence described by eq. (2) will be linear when λ is constant. This is the case when the sample is in the state of magnetostriction saturation, where $\lambda = \lambda_s$.

II. EXPERIMENTAL

The FMR spectrometer constructed in our institute was used for the measurements at the fixed frequency $f = 9.65$ GHz. A magnet with a 5.5×10^{-2} m gap width yielded magnetic fields ranging from -0.025 to 0.15 T. The measurements were performed at room temperature.

An amorphous ribbon prepared by rapid quenching from the melt was used as a sample. Its geometrical dimensions were of a 2.75×10^{-3} m width, a 3.05×10^{-5} m thickness and a 10×10^{-2} m length, but the active length in the cavity was 2.3×10^{-2} m (see Fig. 1). The chemical composition of the ribbon, given by the producer only qualitatively, consists of Fe, Ni, Si and B.

The sample S (see Fig. 1.) was located in parallel with the lines of the external magnetic field B_0. The tensile tension was realized by fixing one side of the ribbon by a clamp. The other side of the ribbon issuing from the cavity C through the pulley P was loaded with the weight W outside the magnet M.

The possibility of a continuous transition through the zero value of the magnetic field was obtained by an appropriate connection of the magnet coils. The dependence of the FMR signal is illustrated in Fig. 2, where B_{0r} denotes the resonance field of the main resonance peak.

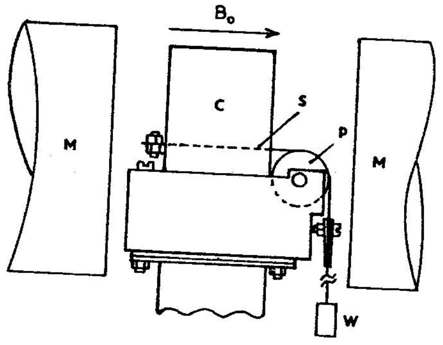

Fig. 1. Application of tensile tension on a ribbon sample in FMR measurements.

III. RESULTS AND DISCUSSION

We have measured the dependence of the resonance field on the time duration $B_{0r} = B_{0r}(t)$ (Fig. 3.) as well as on the acting mechanical tension $B_{0r} = B_{0r}(\sigma)$ (Fig. 4.). The acting time at each load was the same.

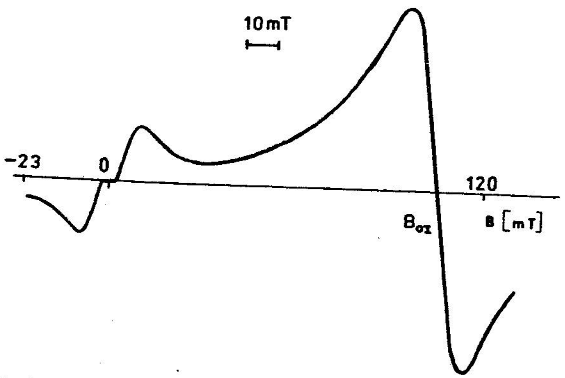

Fig. 2. Derivation of absorption signal of the amorphous FeNiSiB sample.

We can see from Fig. 3. that there are no considerable changes of the B_{0r} field if the action time of the load exceeds 100 minutes. The same action time $t = 5$ minutes was used at each loading because of time. Linear extrapolation of the B_{0r} vs. the σ dependence for $\sigma < 40$ MPa yielded the value 97.4 mT for B_{0r}

at zero tension ($\sigma = 0$). The slope of this linear dependence has the value of $-8.03509 \times 10^{-11}\,\mathrm{T\,m^2\,N^{-1}}$. The value of magnetic polarization $J_s = (0.925 \pm 0.001)\,\mathrm{T}$ was estimated by means of a magnetometer. Thus, from equation (2), assuming that $\lambda = \lambda_s$, we have obtained the value of the magnetostriction coefficient $\lambda_s = 39.4 \times 10^{-6}$.

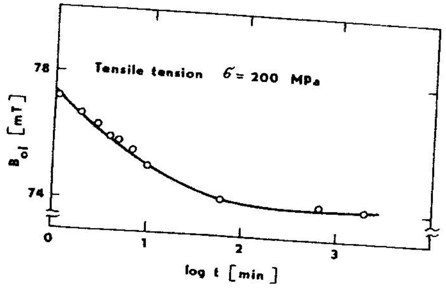

Fig. 3. Dependence of resonance field B_{0l} vs. tension acting time at constant loading.

It is evident from Fig. 2. that considerable absorption changes are at the low magnetic field and at the field B_{0l}. The magnetostriction does not appear at the low field and expression $3\mu_0\lambda\sigma.(2J_s)^{-1}$ in equation (1) may be neglected. Therefore the shape of the resonance signal at the low fields will not change with the variations of σ.

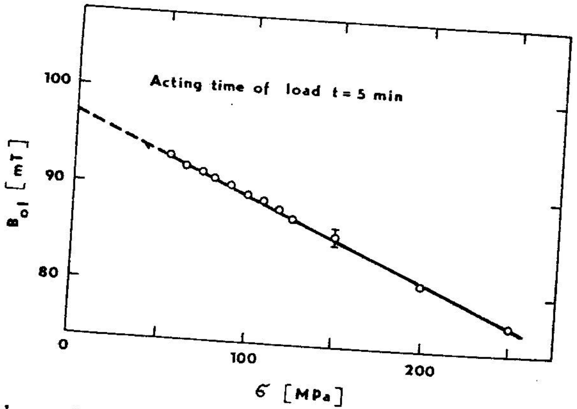

Fig. 4. Dependence of resonance field B_{0l} vs. tension at constant acting time of load.

A different situation arises as regards the absorption at the B_{0l} field. Its minimum value is 75 mT at the used tensions and is larger than the value of B_{0l} at the saturation magnetostriction. Therefore the expression $3\mu_0\lambda_s\sigma.(2J_s)^{-1}$ will be proportional to σ at the B_{0l} fields, which results from a linear dependence B_{0l} vs. σ.

Analysing the reasons of a considerable dispersion of the B_{0l} values in the preliminary measurements we conclude that the resonance field is considerably dependent on the duration of a load action before the beginning of the signal recording.

The coefficient λ_s for amorphous materials with a similar composition studied in [5, 6] is lower than the one we have obtained. We assume that this difference is caused by the finite penetration depth of the high frequency energy absorption. Our experimentally estimated λ_s belongs to the ribbon surface, whereas the ribbon bulk culd have other magnetostriction properties.

IV. CONCLUSIONS

Our experimental results confirm that an additional magnetic field B_σ has to be assumed when the tensile tension is acting on a sample. The FMR method is capable of detecting the variations of this field. The dependence of the resonance field B_0 on time during which the tension acts on a sample was obtained. This dependence would be useful in studying the time evolution of the deformation processes in such materials. The changes of the h. f. energy absorption were observed in the vicinity of the zero value of the applied field B_0, where only a part of an absorption line was observable. With increasing tension the changes at higher fields results in the shift of the resonance line towards the lower fields. Some authors [7] connect the absorption in polycrystalline samples at low fields with the changes of their domain structure. Investigation of the FMR absorption and of the domain structure simultaneously could answer the question of the validity of this assumption also as regards amorphous materials.

REFERENCES

[1] Novák, L., Potocký, L., Uličiansky, S., Kisdi-Koszó, É., Lovas, A., Takács, J., Mlýnek, R.: J. Magn. Magn. Mat. *26* (1982), 118.
[2] Novák, L., Potocký, L., Kisdi-Koszó, É., Lovas, A.: Acta Phys. Slov. *31* (1981), 101.
[3] Hilzinger, H. L., Hillmann, H., Mager, A.: Phys. Stat. Sol. a *55* (1979), 763.
[4] Hajko, V., Potocký, L., Zentko, A.: *Magnetizačné procesy*. Alfa Bratislava 1982.
[5] Du Trémolet de Lacheisserie, E.: J. Magn. Magn. Mat. *25* (1982), 251.
[6] Ferchmin, A. R., Kobe, S.: *Amorphous Magnetism and Metallic Magnetic Materials Digest*. North-Holland P. C., Amsterdam 1983.
[7] Krupička, S.: *Fyzika feritů a příbuzných magnetických kysličníků*. Academia Praha 1969.

Received November 27th, 1986
Revised version received August 25th, 1987
Accepted for publication September 9th, 1987

ВЛИЯНИЕ МЕХАНИЧЕСКОГО НАПРЯЖЕНИЯ НА ФМР-СИГНАЛ В АМОРФНОМ СПЛАВЕ FeNiSiB

В работе приводятся результаты исследований влияния механического напряжени
сигнал ферромагнитного резонанса в области X-полосы (частота $f = 9{,}65$ ГГц) для ле
аморфного сплава FeNiSiB при комнатной температуре. При этом наблюдались дв
симума резонансного поглощения, причем обнаружено, что поглощение в слабом м
ном поле не зависит от механического напряжения. На основе второго максимума аб
ции, который зависит от механическохо напряжения, вычислен коэффициент магнитос
ции.