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DIMENSIONAL ABSORPTION HIGH-FREQUENCY PROPERTIES OF THE CAST GLASS COATED MICROWIRES

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Introduction

Glass-coated magnetic microwires (fig.1) are characterized by a nucleus out of a magnetic alloy, structurally amorphous and metallic conductor, with diameter between around 1 and 40 μm, covered by a Pyrex coating 0,5 to 30 μm thick. That coating, induces strong mechanical stresses in that nucleus that couple with magnetostriction to determine large magnetoelastic anisotropy, and consequently a unique magnetic behavior as dimensional property of the microwire.

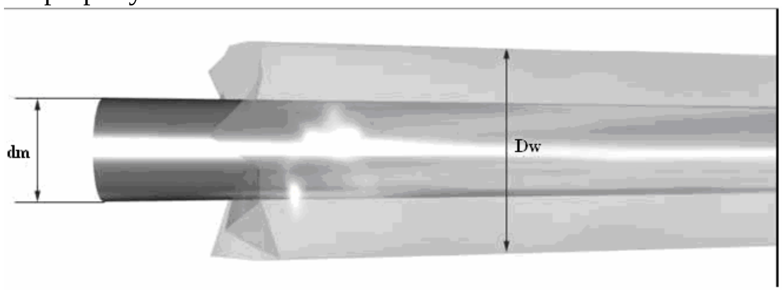
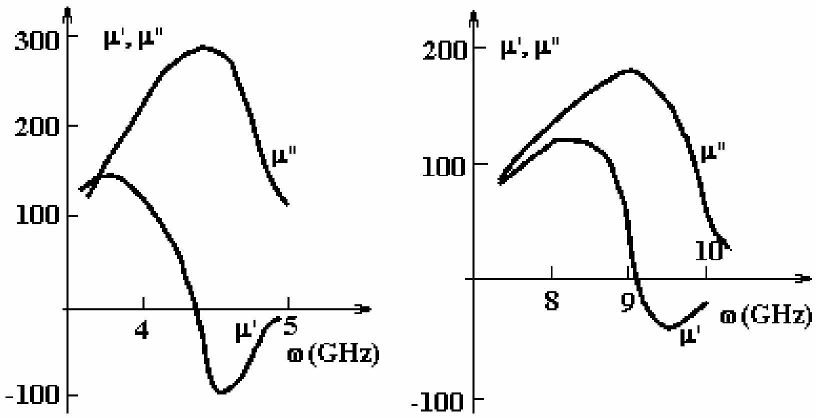


Fig.1. Glass-coated magnetic microwires, where $\boldsymbol{d_m} = 2\boldsymbol{r_m}$ *(*$\boldsymbol{r_m}$ *is the radius of metallic core of the microwire) and* $\boldsymbol{D_w} = 2\,\boldsymbol{R_w}$ *(*$\boldsymbol{R_w}$ *the total radius)*

Natural ferromagnetic resonance (**NFMR**) is an example dimensional effect of the microwire (see [1 –4]).

In the microwave frequency range around **NFMR** dispersion of real **μ'** and imaginary μ'' permeability components are expressed as:

$$\mu(\omega) = \mu'(\omega) + i\,\mu''(\omega)\,. \qquad (1)$$



a *b*

Fig. 2. Real and imaginary permeability components around ***NFMR*** *for* $\boldsymbol{Co_{69}Fe_{15}B_{16}Si_{10}}$ *(a) and* $\boldsymbol{Fe_{69}C_3Mn_2B_{16}Si_{10}}$ *(b) microwires*

Fig. 1,*a* and 1,*b* show the experimental measurements of dispersion of magnetic permeability [1] corresponding respectively to $\mathbf{Co_{69}Fe_{15}B_{16}Si_{10}}$ and $\mathbf{Fe_{69}C_3Mn_2B_{16}Si_{10}}$ microwires exhibiting positive magnetostriction of 10^{-5} (for case (a)) and $5x10^{-5}$ (for case (b)), for which resonance frequency of the NFMR takes values of 4,5 and 9 GHz, and resonance width of 1-2 GHz. The characteristic skin depth δ is given by:

$$\delta = [\rho/4\pi(\mu\mu_0)_e\omega]^{1/2}, \qquad (2)$$

where $(\mu\mu_0)$ is effective magnetic permeability and ρ is the electrical resistance. In a conventional metallic conductor with non-magnetic character and low conductivity skin depth takes typical values in the range 10 to 3 μm in the frequency range from 1 to 10 GHz. In the case of our magnetic microwires δ takes values between around 2 and 0,5 μm.

The frequency of the NFMR is given by (see [2, 4]):

$$(\Omega/\gamma)^2 = (H_e + 2\pi M_s)^2 - (2\pi M_s)^2 \exp\{-2\delta/r_m\} \quad , \qquad \mathbf{(3a)}$$

where $\mathbf{M_s}$ is the saturation magnetization , γ **=2,8 MHz/Oe** is the gyromagnetic ratio and the anisotropy field is $\mathbf{H_e \sim 3\lambda\sigma/M_s}$, where λ is the magnetostriction constant and σ is the mechanical stress originated during the fabrication procedure (see [2-4]).

If $r_m < \delta$, we have :

$$\Omega/\gamma = H_e + 2\pi M_s \quad . \qquad \mathbf{(3b)}$$

If $r_m > \delta$, we have for the NFMR frequency (see [1–4])) :

$$(\Omega/\gamma)^2 = (H_e + 4\pi M_s)\, H_e \qquad (4)$$

The largest absorption will be expected at such conditions for which the imaginary component of the magnetic permeability **μ''** takes the highest values given by:

$$\mu'' \sim \mu_{dc}\, \Gamma\, \Omega \,/\, [\,(\Omega - \omega)^2 + \Gamma^2], \qquad (5a)$$

where μ_{dc} is static magnetic permeability and **Γ** is the width of the resonant curve. Around the resonance frequency eq. (5a) reduces to

$$\mu''/\mu_{dc} \sim \Omega / \Gamma \sim 10 - 10^2. \qquad (5b)$$

Consequently, monitoring the geometry of the microwire (see fig.1. and [1–4]) and the magnetostriction through its composition enables one the fabrication of microwires with tailor able permeability dispersion and for creating radioabsorption materials: i) determining the resonant frequency in a range from 1 up to 12 GHz; ii) controlling the maximum of imaginary part of magnetic permeability; and iii) resolving the width of the resonant curve (see fig.2. and [1–7]).

Radio-absorption screens

Profiting of their outstanding high-frequency properties, pieces of microwires have been embedded in planar polymeric matrices to form composite screens for radio absorption protection. Experiments have been performed employing commercial polymeric rubber around 2 mm thick. Microwires are spatially randomly distributed within the matrix before its solidification. Concentration is kept below 8 g of microwire dipoles (2.0 to 3.5 mm long) per 100g rubber. A typical result performed in anechoic chamber is plotted in fig. 3 for a screen with embedded $Fe_{69}C_5B_{16}Si_{10}$ microwires. As observed, an absorption level of at least 10 dB is obtained in the frequency range from 8 to 12 GHz with a maximum attenuation pick of 30 dB at around 10.8 GHz. In general, optimal absorption is obtained with microwires with metallic nucleus of diameter $2r_m$ = 1–3 μm and length L = 1–3 mm. Such pieces of microwires can be taken as dipoles which length, L, is comparable to the half value of the effective wavelengths, $\mathbf{\Lambda_{eff}/2}$, of the absorbed field in the composite material (i.e., in connection to a geometric resonance) [5–7].

Fig. 3 also shows the frequency absorption spectrum of a screen with $Fe_{69}C_3Mn_2B_{16}Si_{10}$ microwires after being monotonically rotated (90º each spectrum) with respective fixing the sample (case 1, 2, 3 , 4).

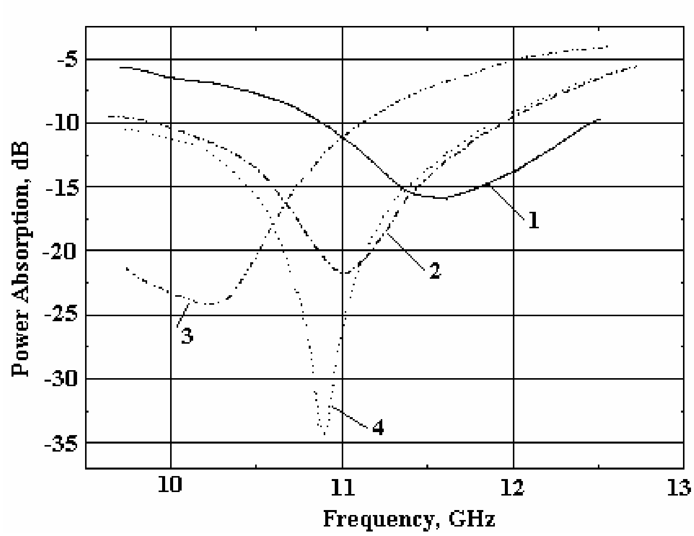


Fig. 3. The absorbing characteristic of screen from microwires with natural resonance in the HF- field in the range of frequencies 10-12 GHz. [6, 7] (The measurement error was less than 10% for the frequency, and while the spread of the attenuation factor was 5–7 dB.)

Different attenuation is seemingly described to the lack of perfect angular distribution of microwires which length not always fit within the screen thickness [6, 7].

Correlation between frequency of **NFMR** (1 to 12 GHz) determined from dispersion of permeability and alloy composition (or magnetostriction between 1 and 50 ppm) of glass-coated microwires has been systematically confirmed. Absorption of composite (microwire pieces embedded into polymer matrix) screens has been further experimentally investigated. Parallel theoretical studies suggest that a noticeable absorption fraction can be described to geometrical resonant effect while concentration effect is expected for thinnest microwires as dimensional metamaterials effect.

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Received 02.09.08

Summary

Correlation between frequency of natural ferromagnetic resonance of the cast glass coated amorphous microwires and high-frequency absorption of a composite material from this microwire is received.