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Giant magnetoimpedance in Vitrovac® amorphous ribbons over [0.3–400 MHz] frequency range

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Abstract

Giant magneto impedance (GMI) effect for as-cast Vitrovac® amorphous ribbons (Vacuumschmelze, Germany) in two configurations (parallel and normal to the ribbon long axis) is studied over the frequency range [0.3–400 MHz] and under static magnetic fields -160 Oe $< H_{DC} < +160$ Oe. A variety of peak features and GMI ratio values, falling within a small field range, are observed and discussed.

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Keywords: Giant magneto impedance; Amorphous magnetic ribbons; Magnetic anisotropy

The giant magneto-impedance effect (GMI) in amorphous ribbons and thin films is of growing interest for a wide variety of potential applications in information storage technology and sensors requiring high sensitivity and large bandwidth [1,2].

Magneto impedance (MI) in a magnetic conductor consists of an impedance change produced by applying a static magnetic field (H_{DC}), usually in the plane, along [LMI] or perpendicular [TMI] to the direction of the probing low-amplitude alternating current (AC). The relative magnetic permeability μ_r of the material and the direction and magnitude of the anisotropy field H_k control the profile of the MI versus field H_{DC} and frequency f. In the LMI case, the MI profile versus field H_{DC} exhibits either a single or a double-peak, when the anisotropy axis (AA) is, respectively, parallel or perpendicular to the current direction. The same behavior is also observed when the frequency f is varied.

For planar geometry (ribbons and thin films) and in-plane uniaxial magnetic anisotropy [2,3], a large GMI ratio (depending on $\sqrt{\mu_r}$)is obtained when the AA direction is transverse to the longitudinal axis of the conductor in the LMI case. Thus, a large relative transverse permeability μ_{rT} resulting from a very small magnetic anisotropy (inherent to amorphous alloys) is necessary to yield a strong GMI effect.

The distribution of the AA direction also influences the GMI effect. In order to interpret the GMI measurements in ribbons, the average direction of the AA can be decomposed into a longitudinal and transverse components along the long and short direction of the ribbon and estimate their contributions separately [4–6].

The purpose of this work is to examine experimentally the GMI effect in the LMI and TMI configurations with different AA direction distributions in order to discriminate among the contributions of the different components.

The GMI measurements were carried out on as-cast amorphous ribbons with nominal composition: $Co_{66}Fe_4Mo_2B_{16}Si_{12}$ (Vitrovac® 6025). This cobalt-rich metallic glass alloy is interesting because of its relative permeability that can reach values as high as 100,000.

Samples (2 mm × 15 mm × 30 μm) were cut parallel (CP) as well as transverse (CT) to the tape axis from an as-cast commercial strip having its AA along the tape roll axis. The AA in the CP ribbon-shaped samples was expected to be oriented, on the average, along its long axis (as checked with hysteresis loop measurements)

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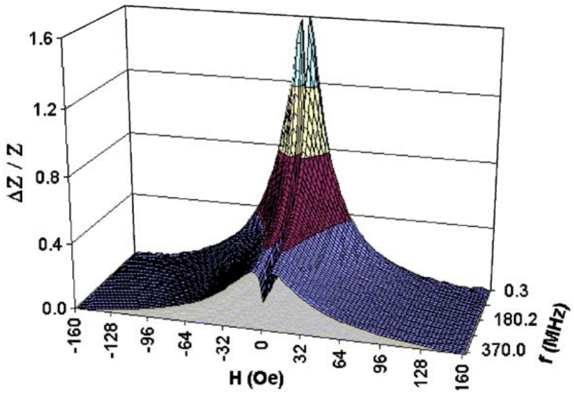

Fig. 1. Three-dimensional plot of GMI ratio $\Delta Z/Z$ as a function of frequency f and magnetic field H_{DC} for Vitrovac® 6025 CP-cut sample for the LMI setup.

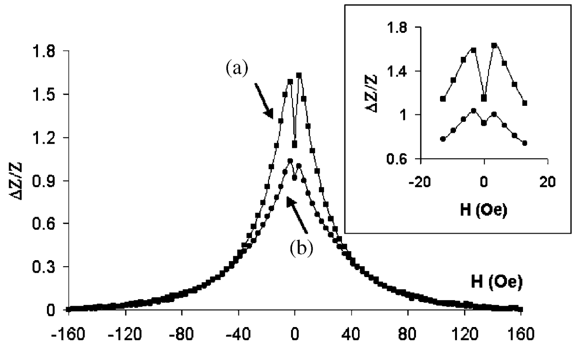

Fig. 2. GMI ratio profile $\Delta Z/Z$ as a function of magnetic field H_{DC} in LMI configuration at a frequency of 10 MHz for Vitrovac® 6025 CP (a) and CT (b) samples. Inset is a zoom-in on the split-peak structure.

whereas the CT samples displayed, as expected, an AA perpendicular to the sample long axis. Finally, the CT samples exhibit a small magnetic anisotropy transverse with respect to the AC current direction. In both cases, a slight dispersion of the AA orientation was obtained. Since the CP and CT samples have the same geometrical dimensions but different orientations of their AA, we conclude that the demagnetizing field H_{dem} is stronger in the CT samples.

Measurements of the GMI ratio versus frequency and field were carried out by applying a field H_{DC} parallel or perpendicular to the sample long axis using a novel broad band measurement method described elsewhere [7]. All measurements were made at room temperature, in the frequency range [0.3–400 MHz], under static fields $-160\ \mathrm{Oe} < H_{DC} < +160\ \mathrm{Oe}$ and low-amplitude AC current (0.1 mA). The MI ratio was determined by the expression:

$$\Delta Z/Z = |Z(H_{DC},f) - Z(H_{max},f)|/|Z(H_{max},f)|,$$

where H_{max} is the maximum value of H_{DC} (that is 160 Oe). Depending on the AA orientations in the CP or CT samples measured in LMI and TMI configurations, a single or a double peak is expected. As an example, in the LMI/CP case (Fig. 1), a single peak is expected to occur but a double peak was obtained because of the presence of a small transverse anisotropy component. Thus, the GMI profile versus H_{DC} is the typical curve [6] doubly peaking at $H = \pm(H_{kT} + H_{dem})$ [8] (H_{kT} is the transverse component of the anisotropy field). Because of the smallness of H_{dem} in the LMI/CP case, the 9 Oe separation between peaks is a value close to $2H_{kT}$.

This contrasts with the TMI/CT case (AA and H_{DC} perpendicular to ribbon long axis) where a large H_{dem} field is obtained, since H_{dem} is proportional to S Ω, the product of the surface S perpendicular to the magnetization and the solid angle Ω subtended at the center of the ribbon by S. In addition, the GMI ratio displays a split-peak Lorentzian-like profile with a separation of about 38 Oe between the peaks rounded by the distribution of anisotropy field H_k (not shown here).

In Fig. 2, a comparison of GMI ratio values for CP and CT samples measured at 10 MHz in LMI configuration shows a drop of the GMI ratio from 160% to 100%.

GMI strongly decreases as the frequency, f, increases and we ran tests to check that it was not due to any parasitic capacitance effects from the measuring apparatus we use. The imaginary part of impedance [9] as a function of H_{DC} and f (not shown here) is very similar to that of total impedance, indicating that total impedance is made essentially of the imaginary part. The real component (not shown here), also displays a rounded split-peak shape (with field separation between peaks comparable to those of impedance), but is quite insensitive to f. This behavior can be ascribed to a more direct dependence on the skin effect that is expected at the frequencies used.

In conclusion, our work illustrates the variety of GMI spectra induced by the dispersion of AA direction and the influence of the magnitude of the demagnetizing field H_{dem} arising from the finite geometrical structure of the samples.

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