Characterization of amorphous FeZrB(Cu) alloys by the inductance spectroscopy method

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Impedance spectroscopy measurements were carried out on amorphous ribbons of nominal compositions $Fe_{93-x-y}Zr_7B_xCu_y$ ($x=6,8$ and $y=0,1,2$), in the frequency range of 5 Hz–13 MHz. Two different geometries were used for measurements: a longitudinal one by using an 80-turn solenoid and the magnetoimpedance geometry, where the ac current flows through the ribbon itself. The obtained results showed a larger initial permeability value for longitudinal domain walls, as compared with transverse ones. Results concerning the propagation field showed the opposite behavior. These results are interpreted in terms of the short-range order arrangements of Fe atoms in these alloys, also known as ''nanoamorphous demixing structures.'' © *2000 American Institute of Physics.* [S0021-8979(00)25408-X]

Amorphous FeZrB(Cu) alloys have been studied extensively because of their usefulness as precursors for magnetically soft nanocrystalline phase, which can be formed by means of a controlled crystallization.[1] As it is evidenced by the radio-frequency collapse of the magnetic hyperfine structure in the rf-Mössbauer spectra, the amorphous phase contains two preferential short-range order sites which are extremely sensitive to the Fe content.[2] These two sites lead to an inequivalent magnetically and also chemically environment. These ''nanoamorphous demixing structures''[3–5] in the undercooled liquid as able to generate subcritical nuclei via relaxation processes as a result of cooperative motion of several atoms. Therefore, it is plausible to link the crystallization behavior of these alloys to the influence of these structures as this process occurs in two steps separated by a wide temperature interval and with many structural differences in their phases.[6]

In this work, the domain wall pattern structures formed in as-quenched samples of the FeZrB(Cu) amorphous alloys is studied by the inductance spectroscopy method, which has demonstrated to be a very useful technique for the magnetic characterization of amorphous and nanocrystalline alloys in the form of ribbons and wires.[7–9]

The magnetoimpedance effect consists of the variations of the impedance response of a ferromagnetic material (submitted to an ac current of small amplitude) when a dc magnetic field is applied. It has been shown[8] that the complex inductance formalism $L^*=L_r+jL_i$ (where L_r is the real part of the complex inductance and L_i the imaginary one) is convenient to investigate the magnetic phenomena L^* can be derived directly from the complex impedance data, Z^*, as $L^*=Z^*(-j/\omega)$, where ω is the angular frequency $\omega=2\pi f$. It has been also shown that by subtracting the impedance values obtained under a saturating dc magnetic field measurement to the zero field measurement run, it is possible to separate the domain wall contribution from the total inductance.

In the present work, the complex magnetoimpedance response of amorphous samples (10 cm long, 0.5 cm wide, and 20 μm thick) of nominal composition $Fe_{93-x-y}Zr_7B_xCu_y$ ($x=6.8$ and $y=0,1,2$) were measured.

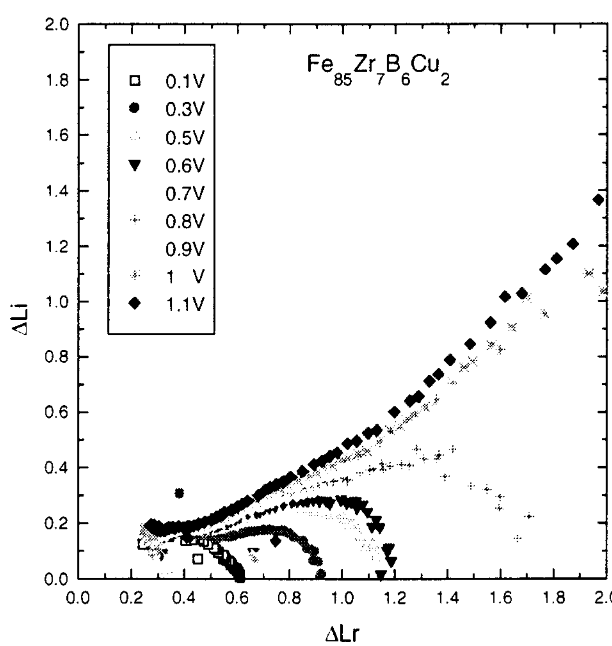

FIG. 1. Complex plots for the studied samples in the longitudinal geometry respect to the ribbon axis.

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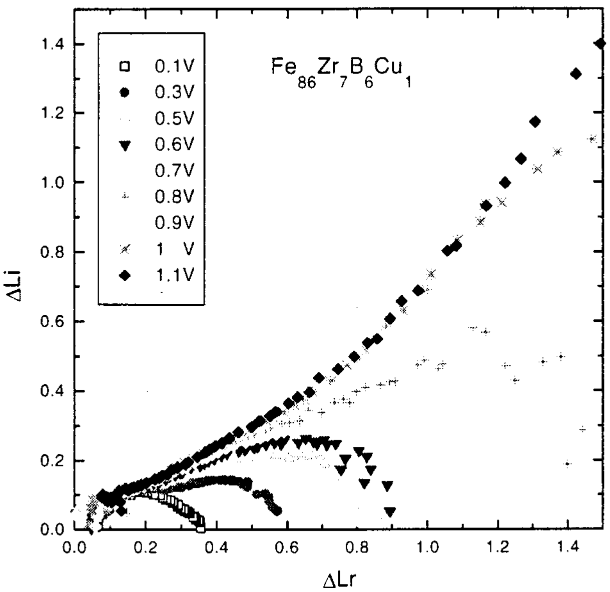

FIG. 2. See Fig. 1 caption.

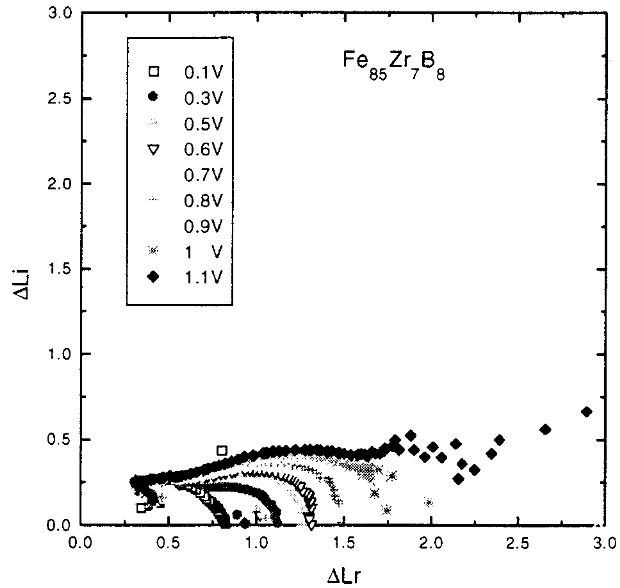

FIG. 4. See Fig. 1 caption.

The complex inductance response was obtained also in the longitudinal direction with respect to the ribbon axis, in the frequency range of 5 Hz–13 MHz by means of a system including a HP4192A impedance analyzer.

For the transverse geometry measurements, samples were directly submitted to the ac current from the impedance analyzer by making electrical contacts as explained elsewhere.[8] Longitudinal magnetization measurements were performed by using a 80-turn solenoid to apply the ac magnetic field. Both types of measurements were carried out under a zero and a dc applied field of 80 Oe, generated by an additional solenoid. All the results presented here were obtained by subtracting the high dc field value from the zero field point by point, for the measurement at each frequency. We have recently shown that this procedure allows us to retain the domain wall permeability and eliminates the contribution from spin rotation processes.[7]

We analyze first the results obtained in the longitudinal geometry. These trends are clear in complex plots of the imaginary part of inductance as a function of the real part, Figs. 1–4. The change in magnetization process appears as a change from a semicircle for low field amplitudes, to an open curve for medium fields, and to an almost linear ''spike'' for very high fields.[8]

The Fe content has the effect of increasing the initial permeability, as shown by the increase in semicircle diameter, Figs. 1–4 (note that the L_r logarithmic scale in the spectroscopic plots flattens the relative values).

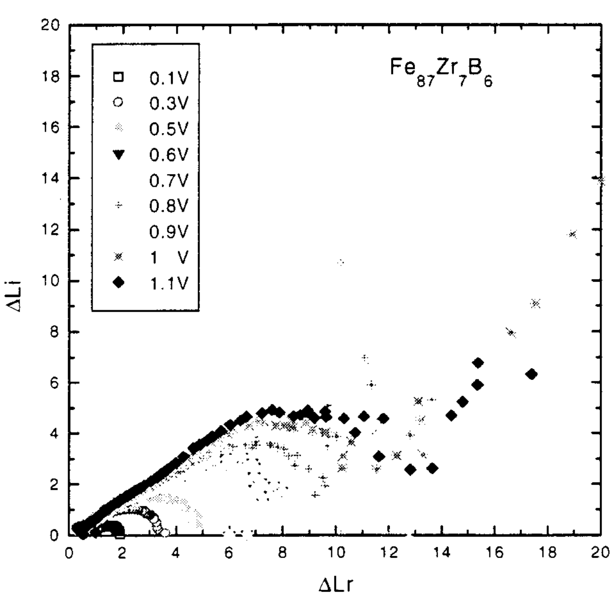

FIG. 3. See Fig. 1 caption.

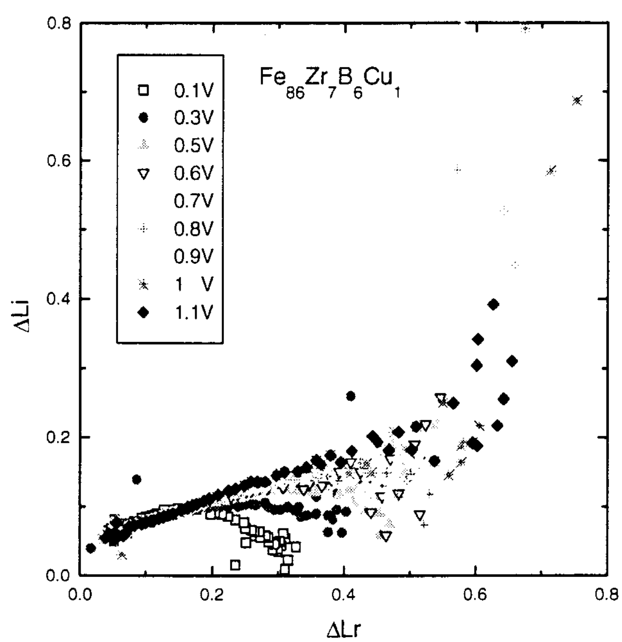

FIG. 5. Complex plots for some of the studied samples in the transverse geometry respect to the ribbon axis.

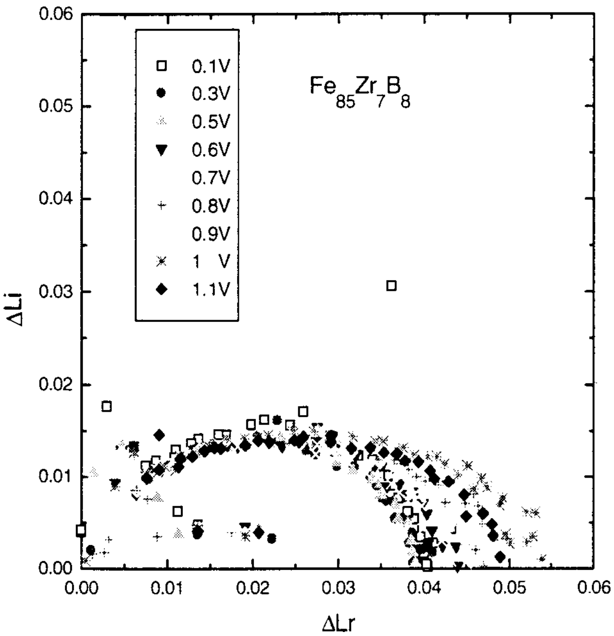

FIG. 6. See Fig. 5 caption.

The experiments with the transverse geometry, where the ac current flows through the sample and produces a perimetral magnetic field, also showed a clear tendency to form semicircles in the complex plots, as appears in Figs. 5 and 6. For most of the studied field amplitudes, the locus of the points remain a semicircle, showing that for the transversal geometry, domain walls are more tightly pinned than in the transversal case. Also, from the observed L_r values, it appears that permeability values are smaller by about an order of magnitude. The changes in composition show that initial permeability (proportional to the semicircles diameter) increases with an increase in both iron and copper.

The obtained results point to a complex arrangement of transversal and longitudinal domain walls, where the latter ones are larger (higher L_r values) and less tightly pinned. For both types of domain walls, it appears that the Fe content leads to an increase in permeability. This result can be ascribed to the existence of ''nanoamorphous demixing structures'' in the undercooled liquid, which produce two preferential short-range order sites for the Fe atoms. Therefore, it seems plausible to expect that these atom rearrangements tend to produce more stable longitudinal domain walls than transverse ones in the amorphous samples as is evidenced by the complex inductance plots.

The inductance spectroscopy method has been proved to be a very useful technique for analyzing and evaluating the domain wall structures formed in the amorphous FeZrB(Cu) alloys of several compositions. An interpretation of these results in terms of the nanoamorphous demixing structures has been proposed.

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