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Transverse magnetization and giant magnetoimpedance in amorphous ribbons

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Abstract

In the classical approach giant magnetoimpedance (GMI) is driven by the transverse permeability of the sample, as excited by the current flowing through it. Transverse permeability is usually taken as a constant, while detailed magnetization processes are important for the interpretation of GMI data. In most cases the transverse permeability (or magnetization) is only guessed by looking at the longitudinal magnetization curve and direct determinations of such parameter are scarce in the literature.

In this work we report on the operation of a simple setup which provides the transverse magnetization of amorphous ribbons as a function of the current intensity flowing through it, by means of the magnetooptical kerr effect (MOKE).

The system has been tested on low magnetostriction amorphous ribbons of very soft character with both longitudinal and transverse anisotropy. The transverse magnetization as a function of both the current and a DC longitudinal field applied, was compared with magneto impedance measurements.

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It is well known that the giant magnetoimpedance (GMI) is originated by the dependence of the penetration depth of AC currents on the transverse permeability that is strongly sensitive to small external magnetic fields (bias field) applied along the sample longitudinal axis. In this way the GMI effects is only appreciable where the penetration depth is smaller than the sample thickness which corresponds to frequencies higher than 1 MHz for 20 μm thick ribbons. For much higher frequencies, great changes of GMI curves have been reported [1] that could be partially related to an inhomogeneous transverse permeability that is expected to depend on the distance from the sample surface. Anyway, direct determinations of the transverse permeability are scarce in literature because the experiments have to overcome the difficulties coming from the strong demagnetizing effects that appear when an external magnetic field is applied in transverse direction. Very often the dependence of the transverse permeability on the applied longitudinal field in ribbons and wires is only deduced in a indirect way from the longitudinal bulk magnetic behavior, also presumably different from the surface one. The aim of

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this work is precisely to make a direct evaluation of such transverse surface magnetic properties by means of the magnetooptical kerr effect (MOKE) in longitudinal configuration when the driven field is produced by a current flowing through the sample. This mimics the GMI conditions and avoids the large demagnetizing factor. In addition, this technique brings together two interesting characteristics, namely, it is sensitive to depth (up to 100 nm from surface) and it is a vector magnetometry in the sense that it provides the magnetization component in a given direction.

We have analyzed two amorphous alloys of similar composition, $Co_{70}Fe_5Si_{15}B_{10}$ (called A in the text) and $Co_{69}Fe_4Si_{15}B_{12}$ (B) with very low magnetostriction obtained by the standard single roller quenching method in the form of ribbons 20 μm (A) and 30 μm (B) thick. The first one (A, 20 mm long) has an stress-induced transverse anisotropy and the second one (B, 80 mm long) has a longitudinal anisotropy.

The experimental setup to obtain the transverse magnetization as a function of the current intensity flowing through the ribbon is based on the usual longitudinal magneto-optical arrangement [2,3]. Incident s polarized light rotates its polarization plane after reflection on the sample and a signal proportional to the p polarized reflected intensity (perpendicular to the incident one) is recorded by filtering out the reflected s polarized component with a nearly crossed polarizer. In this way, the output voltage signal from the photodetector is proportional to the component of the surface magnetization parallel to the reflection plane (horizontal plane) with no contribution from any perpendicular component in the plane of the sample. Since the sample ribbon axis is perpendicular to the horizontal plane, the system is only sensitive to the transverse magnetization. In this way the lack of demagnetizing effects becomes the main goal of this arrangement; these effects are essentially not present because magnetic field H lines close themselves without crossing the sample surface. The current intensity is driven by a function generator that can be operated in the burst mode (pulsed cycles) in order to increase the maximum current without increasing the RMS value and so preventing Joule heating. This procedure is very useful to reach saturation in the transverse direction if longitudinal anisotropy is present. In this way the kerr signal can be normalized to the saturation magnetization measured by a conventional fluxmetric induction method. In order to reproduce the experimental conditions of the magnetoimpedance measurements the DC transverse permeability has been recorded as a function of a static magnetic field applied in the ribbon axis (in the vertical direction).

In addition to the measurements previously described, the longitudinal hysteresis loops have been recorded by MOKE technique in both sample surfaces under an alternating (50 Hz) external magnetic field applied along the ribbon, simply by aligning the ribbon in the incident plane.

In Fig. 1 we present the longitudinal hysteresis loops obtained by MOKE for the two samples in both surfaces, one in contact with the cooler (rough in (a) and (c)) and the other one free (shinning in (b) and (d)). Apart from other features, the loops resemble the expected ones from samples with transverse anisotropy

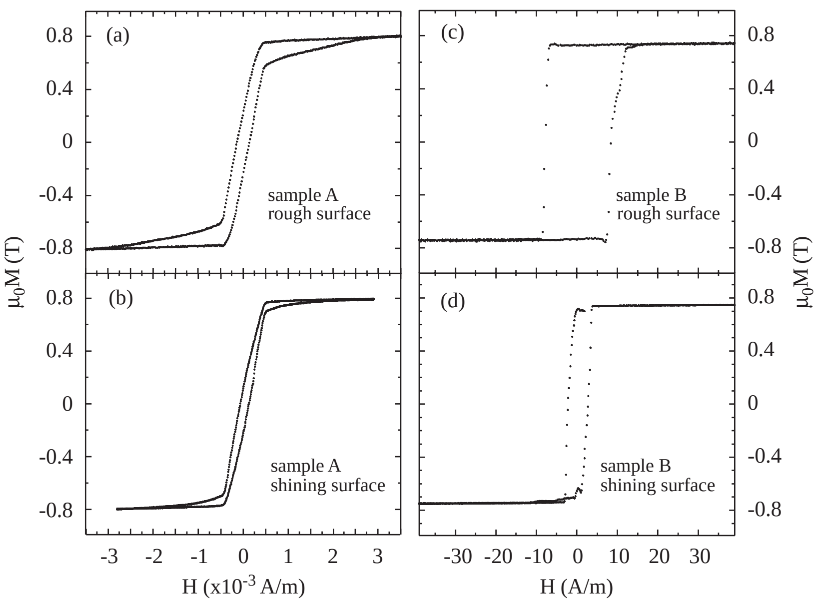

Fig. 1. Magnetization loops in the longitudinal direction in both surfaces of the ribbons for the sample A (a) and (b) and the sample B (c) and (d).