Q-6

Temperature dependence of permeability and magnetoimpedance effect in $Co_{70}Fe_5Si_{15}Nb_{2.2}Cu_{0.8}B_7$ ribbons

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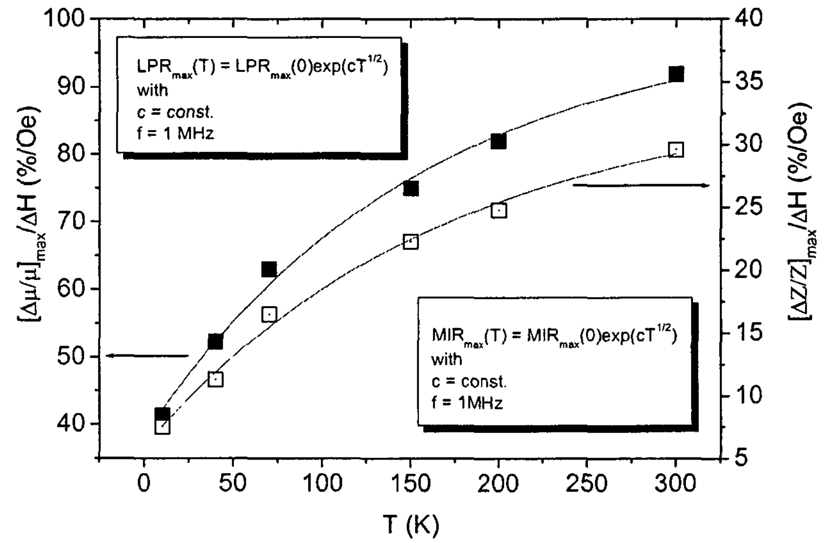
During the past decade, giant magnetotransport phenomena such as giant magetoresistance (GMR) in thin films [1] and in manganese perovskites [2], and, giant magnetoimpedance (GMI) in soft magnetic amorphous ribbons [3], have brought much interest in the basic physical understanding and their applications as magnetic recording heads and in magnetic sensors technology. Among the parameters required for the quality of a magnetic sensor, temperature dependences of GMR and GMI profiles are playing an important role. In the present work, we have studied temperature dependences of the longitudinal permeability and giant magnetoimpedance effect in $Co_{70}Fe_5Si_{15}Nb_{2.2}Cu_{0.8}B_7$ amorphous ribbons expecting as a promising candidate in the domain of magnetic sensors [4].

The $Co_{70}Fe_5Si_{15}Nb_{2.2}Cu_{0.8}B_7$ ribbons we studied have the width of 4 mm and the thickness of 20 μm and were prepared by the rapid quenching technique. The X-ray diffraction (XRD) confirmed about the quality of the sample. The resistivity is of 0.75×10^{-5} Ωm measured using the four-probe method. The permeability and impedance measurements were carried out along the ribbon axis with the longitudinal applied magnetic field. The sample was cut out about 15 mm in length for all measurements. A schematic diagram of the measurement system can be found elsewhere [3].

The magnetoimpedance ratio (MIR) can be defined as $MIR(\%) = 1 - |Z(H)/Z(H_{\max})|$, where H_{max} is the external magnetic field sufficient to saturate the impedance and equals to 150 Oe for our present work. Similarly, the longitudinal permeability ratio (LPR) measured as a function of the external magnetic field can be also defined as $LPR(\%) = 1 - |\mu(H)/\mu(H_{\max})|$. In the previous studies [4,5] it has been shown that the change in the magnetoimpedance is closely related to that of the longitudinal permeability. Meaningfully, the evaluations for GMI effect in amorphous alloys can be realized either by the MIR measurements or the LPR measurements. In this work, the LPR was measured as a function of the external magnetic field at various temperatures and frequencies. The obtained results show that the magnitude of LPR decreases with increasing frequency from 100 kHz to 5 MHz while increases slightly with the measured temperature between 10 and 300 K (at the fixed same frequency). It is worthy noting that there is a noted change in the shape of LPR curves with increases of the measured frequency and temperature. The LPR curves become narrower, in a clean tendency, with increasing frequency and also with increasing temperature (at the fixed same frequency). This behavior is different from that observed on the MIR curves where beside their magnitude and shape increase with frequency, the further broadening in these curves with increasing temperature, which has already been reported in the previous works [3,4].



The temperature dependence of $[\Delta\mu / \mu]_{max} / \Delta H$ and $[\Delta Z / Z]_{max} / \Delta H$ at a frequency of 1 MHz for the sample of $Co_{70}Fe_5Si_{15}Nb_{2.2}Cu_{0.8}B_7$.

The above difference can be due to the increase in impedance and the reduction of longitudinal permeability as frequency increases. Also, the increase in MIR and LPR with the increase of the measured temperature (see Figure) results from the enhancement in magnetic permeability of the sample, since the magnetic permeability is sensitive to temperature indeed. In other words, the exchange energy between magnetic moments at low temperatures (~10 K) is larger than that at high temperatures (~300 K). For this reason, the circular motion of magnetic moments at low temperature might be frozen, which in turn results in lower magnetic permeability and thus the smaller MIR. For a further thorough understanding, we depict the temperature dependence of LPR and MIR at a frequency of 1 MHz and have found that both LPR and MIR with respect to the full width of their haft peak ΔH, defined as $[\Delta\mu / \mu]_{max} / \Delta H$ and $[\Delta Z / Z]_{max} / \Delta H$ respectively, increase exponentially as the measured temperature increases (see in Figure).

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