Magnetoimpedance and Magnetic Properties of Magnetic Electrodeposited Tubes

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An overview of the magnetoimpedance effect as well as magnetic properties observed on electrodeposited materials will be given.

The so called magnetoimpedance effect on ferromagnetic materials is a simple phenomenon which describes the alteration of the material's impedance due to the changes on the penetration depth of an ac current circulating on the material. It is well known that when an ac current reaches high enough frequencies, it can circulate only through a thin outer shell of a material, an effect known also as *skin effect* (1). The total penetration of the current is a function of the material's permeability, conductivity and the current frequency. By changing some of these properties, e.g. its magnetic permeability, one can change the penetration depth and the effective current cross section distribution. This is the basis of the giant magnetoimpedance effect (GMI) on amorphous soft ferromagnetic wires, in which the current penetration depth is dramatically changed by the application of an external magnetic field (2).

Besides amorphous wires and other homogeneous magnetic materials, the GMI effect has been observed as well on electrodeposited heterogeneous materials. Beach and Berkowitz reported GMI on FeNi eletrodeposited on BeCu wires (3). Other authors also reported some GMI studies in CoP eletrodeposited on Cu wires (4-5). These materials consist of an inner Cu wire or tube in which a thin CoP amorphous layer is electrodeposited. Studies of the field dependent impedance on these composites show huge variations on the real part of the complex impedance, and attribute these changes to cross section current distribution changes (5). Figure 1 show the field dependent complex impedance measured on CoP electrodeposited over Cu wires. To understand the GMI better it is useful to know the ac transport and current distribution on these materials.

There are many studies on heterogeneous magnetic wires and tubes and thin films manly are concentrated on $Co_{90}P_{10}$ materials with different magnetic layer thickness, electrodeposited over either Cu wires or tubes by usual electrolytic techniques, in galvanostatic mode. The complex impedance on these materials was measured with a conventional 4 probe method, using a high frequency lock-in amplifier and a current sensor in order to accurately separate the in an out of phase components of the measured impedance. Beside experimental results, the aid of analytical and computer models based has been proofed useful to calculated the cross section current distribution on these heterogeneous wires and tubes. These models solve the Maxwell equations for the geometry under consideration (cylindrical) to arrive on the radial current distribution of the samples. The model also gives the possibility to calculate the impedance and its changes upon external longitudinal magnetic fields. Results show that in certain frequency and external field conditions, most of the current circulates on the CoP layer, a situation that is drastically changed by the changes on the external field, as observed experimentally (see Figure 1, f=1MHz).

Although much work has been done in cylindrical geometries, some efforts has been made to obtain good quality thin films of CoP over other substrates than Cu, e.g. the production of CoP over Si with improved surface quality, and showing interesting magnetic behavior (7). These new CoP structures are good candidates for GMI observation at higher frequencies.

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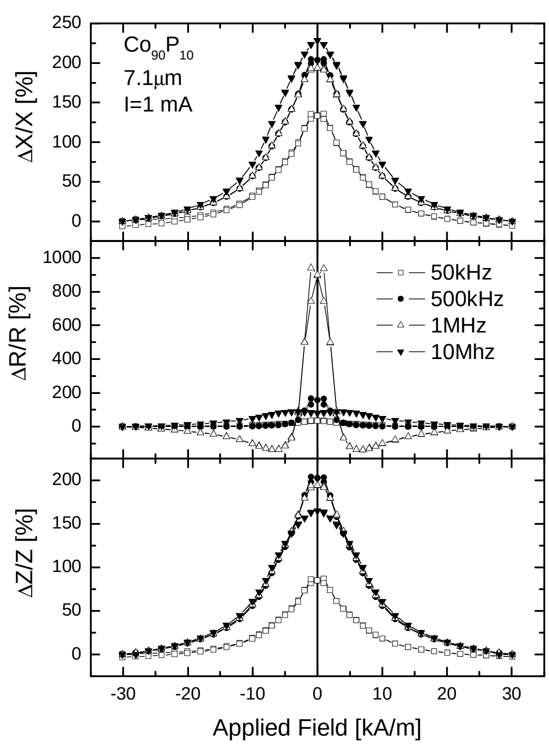

Figure 1: Real (R), imaginary (X) and total (Z) magnetoimpedance ratios as a function of frequency in a CoP electrodeposited wire.