MAGNETIC PROPERTIES AND MAGNETO-IMPEDANCE IN COLD-DRAWN COMPOSITE WIRES PERMALLOY-COPPER

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Introduction

The giant magneto-impedance (GMI) effect has been observed in soft magnetic wires, fibers, ribbons, thin films and sandwich structures (see for example [1,2] and references therein). The growing interest in the GMI has been triggered by the possible applications of this phenomenon in high sensitivity magnetic sensors and magnetic heads. Recently it was shown [3,4] that a composite wire consisting of an inner core with a conductivity larger than that of an outer ferromagnetic shell is the promising candidate for GMI devices. The presence of the high conductivity inner core can significantly increase the amplitude of the GMI effect. The composite wire can be fabricated by electrodeposition or sputtering of ferromagnetic layers on a non-magnetic wire. However using these methods it is difficult to provide the optimal ratio of the inner core diameter d to the wire diameter D because the outer shell should be rather thick (> 10 μm) for the sensors operating in a linear mode [4]. We present the results of the experimental study of magnetic properties and GMI in composite wires fabricated by a modified cold-drawing technique. This method is very simple and can be used for commercial production of composite wires from arbitrary materials in a wide range of parameters d and D.

Experimental

The composite wires NiFe/Cu were produced by pressing the bulk composite blank, its single-draft drawing and subsequent annealing at 800-1000°C. The diameter of the Cu inner core was in the 20-120 μm range, and the NiFe outer shell was 10-40 μm thick. Magnetostatic measurements were carried out using a vibrating-sample magnetometer-anisometer at various orientations of the magnetic field with respect to the wire axis. The GMI effect was measured in a frequency range of 50-1200 MHz by wave-guide technique. The high-frequency current was less than 10 μA; this allows us to neglect possible nonlinear effects. The external magnetic field was created by solenoid and oriented along wire axis.

Results and Discussion

The composite wires exhibit soft magnetic behavior similar to permalloy films and amorphous wires. The coercitivity does not exceed 1 Oe. The real (R) part of impedance Z=R-jX is shown in Fig.1.

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All the composite wires NiFe/Cu exhibit the GMI effect. The impedance of the NiFe wire without Cu inner core, used for comparison, depends very slightly on magnetic field. It substantiates the theoretical prediction [4]. The amplitude of the GMI effect in the composite wires at high frequencies is comparable with that for conventional wires but did not reach the theoretical estimation [4] based on the simple model with the axial type of magnetic anisotropy in the outer shell.

At present time, there is not a definite picture of the magnetic microstructure of the composite wires. Our magnetostatic measurements clearly indicate on the presence of the longitudinal magnetization component. On the other hand, we estimate theoretically the amplitude of GMI effect for a composite wire with circumferential magnetization in the outer shell and find out that it can be even larger then for the case considered previously [4]. Therefore the current annealing or other methods of creating the circumferential anisotropy should be used to improve the GMI response.

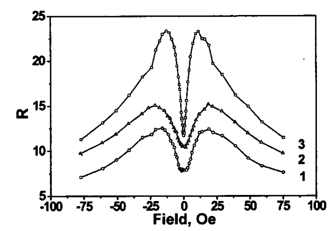

Fig.1 Field dependencies of the active impedance R of composite wires NiFe/Cu with different inner d and outer D diameters: 1. d= 65 μm, D=100 μm; 2. d= 57 μm, D=85 μm; 3. d= 33 μm, D=49 μm. Frequency 500 MHz.

Our study of the cold-drawn composite wires show that this technique has many advantages over electrodeposition and sputtering as lower cost, easier manufacture, the possibility to use arbitrary constituent materials and to produce wires in a wide range of the inner and outer diameters.

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