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Stoner-Wohlfarth model for hysteretic giant magnetoimpedance

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I. INTRODUCTION

Theoretical investigations of the various magnetic parameters affecting the GMI have used two theoretical models for considering the rotational magnetization. [1]

One of the model is based on the magnetization due to the rotational magnetization for the transverse permeability [2] and is known as the Stoner-Wohlfarth model. When the magnetization under an applied field is assumed to jump from a metastable to a stable state, that is, when the minimum energy condition is taken, the calculated profiles during the magnetization show symmetric two-peak behaviors, and the profiles are the same as those obtained for the induced volatge by using the impedance tensor along with anisotropy parameters. The asymmetric GMI profiles are qualitatively well described by a modified Stoner-Wohlfarth model which introduces uniaxial and unidirectional anisotropies. [3] However, there is still much discussion of the calculation and the analysis methods for the Stoner-Wohlfarth model related to the characteristics of hysteresis and asymmetry.

The purpose of this research is clarify the validity of the Stoner-Wohlfarth model in the hysteretic characteristics of GMI related to anisotropic configuration. To that end, GMI profiles have been measured in Co-based amorphous ribbons with various anisotropy angles, and the results have been compared to those obtained by using the Stoner-Wohlfarth model.

II. EXPERIMENTAL

A set of rectangular samples of $Co_{66}Fe_4B_{15}Si_{15}$ (15-μm thick, 2-mm wide, and 50-mm long) were annealed at 180 °C under an applied magnetic field H_a. The two components of the magnetic field were controlled by using two-dimensional Helmholtz coils. The magnitude of the resultant field (vector sum) was 60 Oe, and the anisotropy angles θ_k due to the annealing field varied from 0° to 90° relative to the transverse direction. The absolute value of the complex impedance, *Z*, was measured by using an impedance analyzer (HP4192A) with four terminal contacts. A cyclic magnetic field *H* was applied to the ribbon axis by using a Helmholtz coil and a step-like changing current. The amplitude of the ac probe current was kept at a constant value of 5 mA during the cyclic sweep of *H*.

III. RESULTS AND DISCUSSION

The hysteretic characteristics of giant magnetoimpedance (GMI) profiles have been measured in Co-based amorphous ribbons with various anisotropy angles θ_k, and the results have been compared to the profiles obtained using the Stoner-Wohlfarth model. When the magnetization under the applied field is assumed to jump from a metastable to a stable state, the calculation reveals GMI profiles with two symmetric peaks for $\theta_k < 60^\circ$ and with one peak for $\theta_k \geq 60^\circ$. However, when the angle of the magnetization is assumed to remain in a metastable state without jumping, the profile shows divergences in the positive and the negative field regions for increasing and decreasing fields, respectively, where a divergence indicates a hysteretic asymmetry in the GMI profile for increasing and decreasing fields.

The negligible hysteresis of the field of the dip in the measured GMI profiles is close to that obtained from a calculation with a magnetization jump. However, the hysteretic asymmetry for anisotropy angles in the range of $20^\circ \leq \theta_k < 60^\circ$ are well described by a divergence in the calculation without a magnetization jump. The asymmetry for $\theta_k \geq 60^\circ$ is possibly due to a divergence, but the shapes of the measured profiles are different from those of the calculated ones. From the view of asymmetry and shape, it is concluded that the Stoner-Wohlfarth model adequately describes the small hysteretic asymmetry of GMI profiles for the anisotropy angle range of $20^\circ \leq \theta_k < 60^\circ$ at a frequency of 10 MHz in Co-based amorphous ribbons.

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