Micromagnetic analysis of dynamic magnetization process in an amorphous wire for MI sensors

Y. Uehara, A. Furuya, K. Shimizu, J. Fujisaki, T. Ataka, T. Tanaka, H. Oshima*
(Fujitsu Ltd., *Fujitsu Laboratories Ltd.)

MI sensors based on the magneto-impedance effect in amorphous wires are nowadays widely used in electric compasses, thanks to their small size and high sensitivity [1]. Recently, MI sensors with ultrahigh sensitivity have been studied for application to wearable computers and medical devices [2]. To realize these applications, it is of prime importance to analyze dynamic magnetization process in amorphous wires. In this symposium, we introduce micromagnetic analysis of dynamic magnetization process in an amorphous wire by using Landau-Lifshitz-Gilbert (LLG) equation taking into account the eddy current.

A schematic structure of an MI sensor is shown in Fig.1. A pickup coil is wounded around an amorphous wire. The amorphous wire has a circular magnetic anisotropy arising from the coupling between negative magnetostriction and frozen-in stress. Without external magnetic field H_{ex}, the magnetization in the wire forms the vortex structure in the *yz* plane, as shown in Fig.1. When H_{ex} is applied, the magnetization is tilted to the *x* direction by the field. As the pulse current whose change rate is in the order of MHz-GHz is applied, the magnetization turns back into the *yz* plane due to the Oersted field generated by the current. Simultaneously, the pickup coil detects the change in magnetic flux that arises from the rotation of the magnetization. Because of the high frequency of the current, it is necessary to take into account the eddy current effect in the wire to accurately calculate the dynamics of the magnetization process.

In the LLG simulation, the amorphous wire is treated by a 2D model, assuming that the magnetization distribution in the *x* direction is uniform. It is because their typical length (several hundred µm) is much larger than their diameter (~10 µm), and can be approximated as infinite. The pulse current field including the eddy current effect is incorporated into the effective field in the LLG equation. Fig.2 shows the magnetization process with and without the eddy current effect in the wire. The diameter of the wire is 10 µm, and the mesh size is 20 nm to compute the magnetic domain structures accurately. Saturation magnetization M_s, circular magnetic anisotropy H_k, and resistivity ρ are 1 T, 500 A/m, and 130 µΩcm, respectively. The pulse current height is 0.39 A and the rise time is 0.8 ns. The initial magnetization is aligned in the axial (*x*) direction. The magnetization rotates toward the *yz* plane due to the circular anisotropy and the pulse current field. As shown in Fig.2, the eddy current affects the motion of the magnetization drastically. In this symposium, we will show some simulation results to understand the phenomena in the amorphous wire.

Reference
1) http://www.aichi-mi.com/mi-technology/.
2) T. Uchiyama *et al*., IEEE Trans. Magn., 48, 3833 (2012).

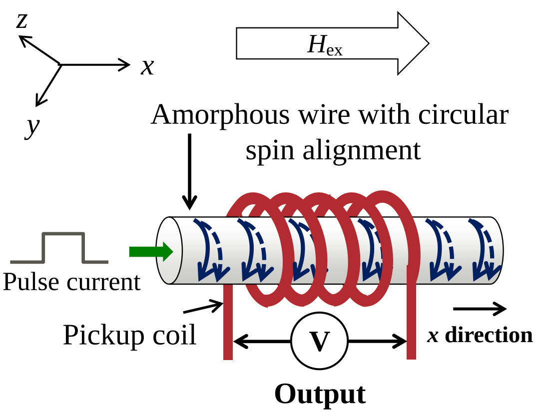

Fig.1 Structure of the MI sensor element

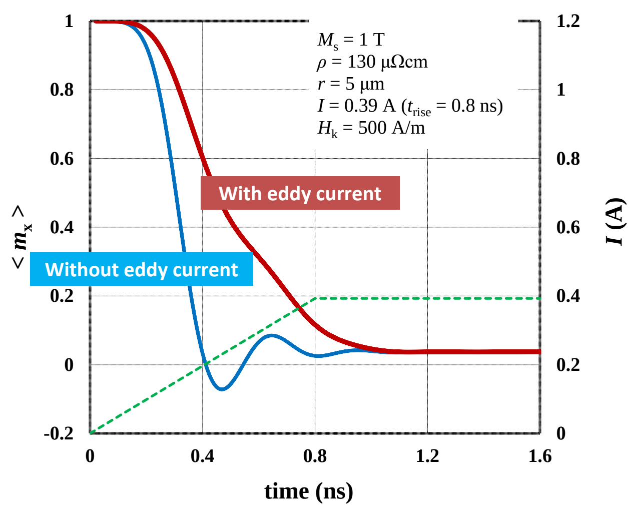

Fig.2 Response of magnetization in the wire to the pulse current with/without the eddy current effect