Magnetic tunnel junctions using perpendicularly magnetized synthetic antiferromagnetic reference layer for wide-dynamic-range magnetic sensors

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Magnetic tunnel junctions (MTJs) have been studied for application to various magnetic sensors in the automotive industry. It is estimated that the magnetic sensors should have a dynamic range wider than ±2 kOe in certain cases. A dynamic range in an MTJ is confined to the value of a reversal magnetic field of the reference layer in the case that the value is smaller than the anisotropy field H_k value of the free layer. To achieve such a wide dynamic range, it seems effective to utilize a perpendicularly magnetized synthetic antiferromagnetic (p-SAF) structure exhibiting a large exchange coupling field H_{ex}.[1)] In this study, we developed CoFeB/MgO/CoFeB-MTJs using a p-SAF reference layer for magnetic sensor applications.[2)]

MTJ films were deposited by using a dc/RF magnetron sputtering system. The stacked structures were Si/SiO_2-substrate/buffer layers/[Co/Pd]-based SAF structure/MgO (2)/$Co_{40}Fe_{40}B_{20}$ (t_{CoFeB} = 1.8, 2.4, and 3)/capping layers (unit in nm). The MTJ films were microfabricated into circular junctions 80 μm in diameter by a photolithography process, and annealed at 300°C for 1 h in a vacuum. We measured magnetoresistance (MR) properties by a dc four-probe method and magnetic properties with a vibrating sample magnetometer under out-of-plane magnetic fields.

In the [Co/Pd]-based p-SAF reference layer, the two magnetizations are antiferromagnetically aligned near zero magnetic field, resulting in the H_{ex} value as large as 2.7 kOe. This satisfies our requirement for the reference layer with a dynamic range more than ±2 kOe. Figure 1 shows MR curves of the MTJs with various t_{CoFeB}. All the MTJs exhibited linear MR curves, thus confirming we achieved a dynamic range more than ±2.5 kOe. The observed MR ratio decreased as the values of t_{CoFeB} increased. This mainly reflects the magnitudes of the in-plane magnetized free layers' H_k: 6, 12, and 13.5 kOe for t_{CoFeB} = 1.8, 2.4 and 3 nm respectively. We investigated the sensor performance metrics of the MTJs, i.e., sensitivity and nonlinearity, and found that they depend significantly on the H_k values of the free layers. This can be explained by a simple model based on the Stoner-Wohlfarth and Slonczewski models, which gives us a guideline to design the sensor performance metrics. These findings demonstrated that MTJs with a p-SAF reference layer are promising candidates for wide-dynamic-range magnetic sensors.

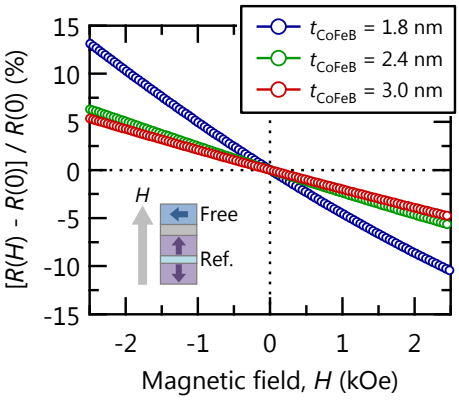

Fig. 1. Normalized minor MR curves of MTJs with various t_{CoFeB}.

This work was supported in part by the Center for Spintronics Research Network, in part by the Center for Innovative Integrated Electronic System, and in part by JSPS KAKENHI JP24226001 and JP16J01812.

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