Magnetic tunnel junction with perpendicularly magnetized sensing layer for magnetic sensor with small nonlinearity and large sensing range

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Magnetic sensor-application of magnetic tunnel junctions (MTJs) has been proposed and demonstrated by many groups[1]. We reported the linear magnetoresistance (MR) behavior in the MTJs with the perpendicularly magnetized CoFeB-sensing layer[2]. The improvement of the sensing properties such as nonlinearity and sensing range is necessary for practical use so far. The Stoner-Wohlfarth (SW) model predicts the nonlinearity can be improved with increasing the anisotropy field H_k in the sensing layer. In this study, we investigated the correlation between the nonlinearity and the H_k by varying the composition and the thickness of the CoFeB-sensing layer.

The stacking structure was Si-substrate/SyF pinned layers/MgO barrier/CoFeB sensing layer /capping layers, deposited by DC/RF magnetron sputtering. We employed $Co_{40}Fe_{40}B_{20}$ and $Co_{20}Fe_{60}B_{20}$ as the sensing layer, and varied its thickness t_{CoFeB} from 1.2 nm to 2.2 nm. The MTJs were microfabricated into the rectangular junctions with the size of $80 \times 40 \ \mu m^2$ by photolithography process. Post-annealing was performed in a vacuum for 1 h at varying temperatures T_a under the in-plane magnetic field of 1 T. We measured transport properties by DC four-probe-method under in-plane magnetic field, and magnetic properties by vibrating sample magnetometer.

Fig. 1 shows the nonlinearity as a function of the H_k of the sensing layer in the MTJs with the linear MR behavior, and its calculation result by the SW model. The nonlinearity is defined as the normalized difference between the data and its linear fit, expressed as the percentage of full scale (FS) in the range of ±400 Oe. The nonlinearity was improved with increasing the H_k, corresponding to the SW model qualitatively. The small nonlinearity (<1%FS) and the large sensing range (≈ 1000 Oe) were successfully achieved by the optimization of the composition and the thickness of the sensing layer. The slight deviation from the SW model may originate in the other mechanism of the magnetization motion such as domain wall motion, or the nonuniformity of the magnetic anisotropy in the sensing layer.
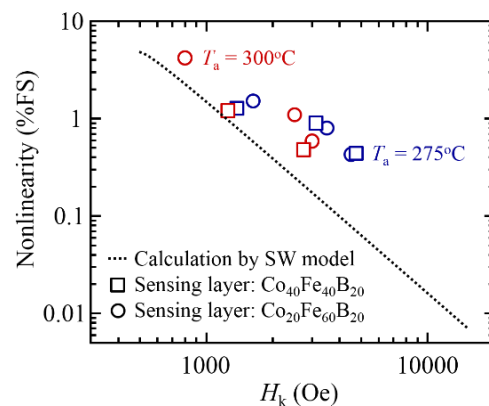

Fig. 1. The nonlinearity as a function of the H_k. The squares and circles are the experimental data for the MTJs with the linear MR behavior. The dashed line is the calculation result by the SW model.

[1] P. Wisniowski, *et al.*, IEEE Trans. Magn. **48**, 3840 (2012).

[2] T. Nakano, *et al.*, The 61st JSAP Spring Meeting, 20a-E7-12 (2014).