Improvement of TMR properties in MTJs with different-sized cylindrical electrodes

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Magnetic field sensors based on magnetic tunnel junctions (MTJs) have been investigated [1], [2]. Recently, we proposed the MTJ sensors with the free layer showing non-uniform magnetic structure to achieve a high sensitivity and observed TMR properties corresponded to non-uniform magnetic structure like a vortex[3]. However, the MTJs with the same ferromagnetic electrodes in diameter showed a lower sensitivity than that in conventional MTJs. In this study, we have investigated the TMR properties in MTJs with various diameter of the reference layer (D_U) to improve the sensitivity.

The films were prepared by the DC/RF magnetron sputtering. The stacking structure was Si,SiO_2-substrate/buffer layers/$Ni_{80}Fe_{20}$ (70 or 80)/Ru (0.85)/$Co_{40}Fe_{40}B_{20}$ (3)/MgO (1.5)/$Co_{40}Fe_{40}B_{20}$ (3)/Ru (0.85)/$Co_{75}Fe_{25}$ (5)/IrMn (10)/capping layer (in nm). The MTJs were fabricated by photolithography and Ar ion milling process. The MTJs were annealed in a vacuum for 1h at the temperature 325°C after the fabrication. The diameters of the magnetic layers were 100 μm for the lower free layer, 50, 70 and 100 μm for the upper reference layer. We measured the TMR properties by DC four-probe method.

Fig. 1 shows the magneto-resistance (MR) curves in the MTJs with D_U = 50, 70 and 100 μm. We observed the maximum TMR ratio of 216% and low saturation field of approximately 5 Oe. We found from the shape of MR curves that magnetization process of the lower CoFeB reflected the magnetic structure of NiFe due to a synthetic antiferromagnetic coupling. The shape of MR curves in MTJs with D_U = 70 and 100 μm showed a non-linear and continuous behavior in low magnetic field range of ±2 Oe due to the non-uniform magnetic structure. On the other hands, for D_U = 50 μm, the MR curve showed a resistance jump at around 2 Oe. This result indicates that a part of magnetic structure in the sensing layer was not vortex but uniform and the magnetization process was discontinuous. We found that optimizations of the size and shape for reference layer are important to obtain a MTJ sensor with magnetic vortex structure and high sensitivity.

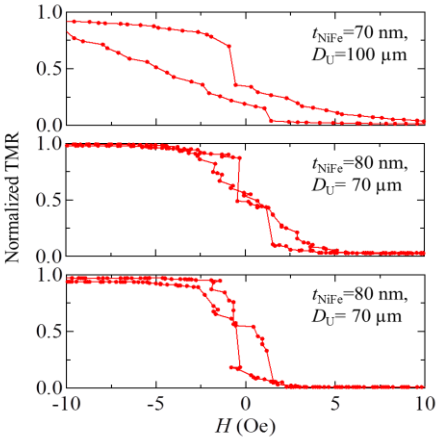

Fig. 1 Magneto-resistance curves in MTJs with the upper layer diameter of 50, 70 and 100 μm.

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