Magnetic Sensor Performance in Pillar-shaped Magnetic Tunnel Junctions with Amorphous CoFeSiB Free Layer

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Bio-magnetic field sensors based on magnetic tunnel junctions (MTJs) are promising because of their small size, low power consumption, and room temperature operation. A high signal (≅ sensitivity = TMR/2H_k, H_k: magnetic anisotropy field) and noise ratio (SN ratio) is required for detection of very small bio-magnetic field (10^{-6} – 10^{-11} Oe). Although the sensitivity was improved using amorphous CoFeSiB electrodes in MTJs with a continuous free layer [1], the sensor performance of the pillar-shaped MTJs was not investigated. In order to develop the integrated array-MTJs for high SN ratio, we need to process the free layer into a pillar shape [2]. In this work, we systematically investigated the CoFeSiB thickness dependence of sensor performance in pillar-shaped MTJs.

MTJ films were deposited by ultra-high-vacuum magnetron sputtering system ($P_{base} < 2.0 \times 10^{-6}$ Pa). The stacking structures of the MTJ films were Si, SiO_2 subs./Ta 5/Ru 10/Ta 5/Ru 10/Ta 5/CoFeSiB 30 - 200/Ru 0.4/CoFeB 3/MgO 1.65/CoFeB 3 /Ru 0.9 /CoFe 5/IrMn 6/Ta 5/Ru 20 nm. The MTJs were fabricated by photolithography and Ar ion milling to 80×40 μm^2 rectangle. After microfabrication into the MTJ devices, they were annealed at 350°C for 1 hour in a vacuum. Subsequently, the devices were annealed again at 260°C for 15 min in the atmosphere to obtain MTJs with the orthogonal magnetic easy axis of free and pinned layers. The TMR properties were measured by the DC four-probe method. The signal voltage was measured at AC magnetic field (3.3 Hz-, H_{PTP}=0.2 Oe-sine wave) and the noise voltage was measured at the frequency of 0.1 Hz – 10 Hz by customized circuits.

Fig. 1 shows the TMR curves in MTJs with various CoFeSiB thicknesses. The magnetic anisotropy field increased with increasing CoFeSiB thickness because of the shape anisotropy. We investigated CoFeSiB thickness dependence of the detectivity which is defined as the (H_{PTP}=0.2 Oe)/(SN ratio=signal/noise). The detectivity was improved by decreasing CoFeSiB thickness and a very high detectivity of 7.8×10^{-4} Oe was achieved in the MTJ with CoFeSiB thickness of 30 nm. This detectivity makes it possible to measure magneto-cardiogram in real time when the 100×100 MTJs are integrated into an array. In addition, the relationship between the detectivity and magnetic domain of the CoFeSiB free layers will be discussed.

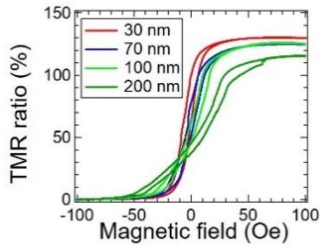

Fig. 1 TMR curves in MTJs with various CoFeSiB thicknesses

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