Magnetic Tunnel Junctions with Amorphous CoFeSiB Free Layer for Highly Sensitive Magnetic Field Sensor Devices

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The discovery of the large tunnel magneto-resistance (TMR) effect in magnetic tunnel junctions (MTJs) with (001)-oriented MgO barriers enables us to design highly sensitive magnetic field sensors such as bio-magnetic field sensors. The sensitivity of magnetic sensor is defined as TMR/2H_k, where H_k is the magnetic anisotropy field of the free layer. Both improvement in the TMR ratio and reduction in magnetic anisotropy are required to achieve a high sensitivity. A very high sensitivity of over 100 %/Oe is required to detect a small bio-magnetic field (ca. 10^{-8} Oe). In previous work, a high sensitivity of 40%/Oe was achieved in MTJs with CoFeSiB(30)/Ru/CoFeB free layer[1)]. In this study, we have drastically improved the sensitivity by optimization of CoFeSiB thickness in CoFeSiB/Ru/CoFeB free layer.

The films were deposited onto thermally oxidized Si wafers using an ultrahigh vacuum magnetron sputtering system (P_{base} < 3.0 x 10^{-6} Pa). The stacking structures of the MTJ films were Si/SiO_2-sub./Ta(5)/Ru(10)/Ta(5)/CoFeSiB ($t_{CoFeSiB}$ = 30, 50, 70, 100) /Ru(0.4)/$Co_{40}Fe_{40}B_{20}$(3)/MgO(2.5)/ $Co_{40}Fe_{40}B_{20}$(3)/Ru(0.9)/$Co_{75}Fe_{25}$(5)/$Ir_{22}Mn_{78}$(10)/Ta(5) (in nm). The MTJ devices were fabricated using photolithography and Argon ion milling. Ar ion milling was stopped in the middle of the MgO barrier, and the top pinned layers were patterned into 80 x 40 μm^2 rectangles. After micro-fabrication, the MTJs were annealed at 350°C for 1 h in a vacuum furnace. The MTJs were annealed again at 260°C for 15 min in the atmosphere to obtain orthogonal magnetic easy axis of free and pinned layers. The magneto-resistance properties were measured at RT by using the DC four-probe method.

We confirmed that CoFeSiB films annealed at 350°C had amorphous structure from both XRD and TEM. Magnetic anisotropy field of CoFeSiB films gradually decreased with increasing CoFeSiB thickness. A coercive field (H_c) of CoFeSiB/Ru/CoFeB free layers in MTJ devices was also decreased by increasing CoFeSiB thickness. The reduction of H_c was achieved by strong coupling between CoFeB and CoFeSiB in the free layer through thin Ru layer. On the other hands, a high TMR ratio of ca. 200% was observed regardless of CoFeSiB thickness. After the second annealing process at 260°C, a linear response to external field was successfully observed and a large sensitivity of 115%/Oe was achieved in MTJs with 100 nm thick CoFeSiB layer (Fig. 1). The observed sensitivity is the highest value among the MTJ devices. This work was supported by the S-Innovation program, Japan Science and Technology Agency (JST).

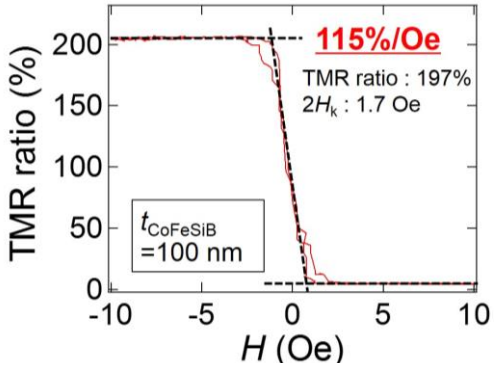

Fig. 1 Magneto-resistance curve in MTJ device with $t_{CoFeSiB}$ =100 nm

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