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Dependence of TMR Ratio on CoFeB Ferromagnetic Electrode Thickness for MgO Barrier Magnetic Tunnel Junctions

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TMR ratio up to 472% at RT and 804% at 5K has been observed for sputtered CoFeB/MgO/CoFeB MTJs consisting of pseudo-spin valve (PSV) stacking structure without antiferromagnetic pinning layer such as MnIr [1]. The optimum annealing temperature (T_a = 450-500℃) that results in the maximum TMR ratio for PSV-MTJs is higher than that (T_a =360-425℃) of exchange biased (EB)-SV MTJs with MnIr layer [2], [3]. The absence of diffusion of Mn into the MgO barrier at high T_a above 450℃ is a factor for the high TMR ratios in PSV-MTJs. However, the details of the CoFeB ferromagnetic electrodes which yield large TMR ratio for PSV-MTJs have not yet been fully clarified.

In this study, we investigated the dependence of TMR ratio on CoFeB ferromagnetic electrode thickness for PSV-MTJs with various CoFeB alloy concentrations.

The rf-sputtered MTJs studied here have stacking structure of substratre/Ta(5)/Ru(20)/Ta(5)/$(Co_xFe_{100-x})_{80}B_{20}(t_{CoFeB})$/MgO(1.5)/$(Co_xFe_{100-x})_{80}B_{20}$(4)/Ta(5)/Ru(10). In CoFeB layer, the B composition was fixed to 20 at% and the composition ratio x of Co and Fe was 25 and 75 at%. The bottom CoFeB layer thickness t_{CoFeB} varied from 2.3 to 6.7 nm by using the slide shadow mask technique. All MTJs were fabricated by photolithography and Ar ion milling with a junction size of 0.8 × 4 μm^2, and then were annealed at T_a = 475℃ for 1h in a vacuum under 4 kOe. The TMR ratio was measured using a dc four-point probe method in the magnetic field range of ±3 kOe.

Fig. 1 shows the TMR ratio as a function of bottom CoFeB layer thickness for the MTJs annealed at T_a = 475℃. A remarkable difference in the film thickness dependence of TMR ratio between $x = 25$ and $x = 75$ is observed. The TMR ratio for the MTJs with $x = 75$ monotonically decreases with increasing t_{CoFeB}. In contrast, the CoFeB thickness dependence for $x = 25$ is not seen clearly, although TMR ratio increases slightly around t_{CoFeB} =4～5 nm. From the results of high-resolution cross-sectional transmission electron microscopy (HRTEM), the difference in the crystallized structure of CoFeB electrode with $x = 25$ and $x = 75$ was observed, which appears to be one of the factors determining the difference of the film thickness dependence of the TMR ratio on the CoFeB composition.

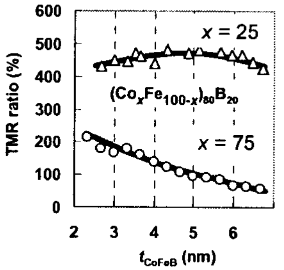

Fig. 1. TMR ratio as a function of CoFeB layer thickness for MTJs with $(Co_xFe_{100-x})_{80}B_{20}$ with $x = 25$ and 75.

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AB06

Spin Transfer Switching in Nanosecond Regime for MgO Based Ferromagnetic Tunnel Junctions

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Current induced magnetization switching[1)](CIMS) is extensively studied for the writing method in magneto-resistive random access memories(MRAMs). This method promises an excellent potential such as, scalability, high speed operation and low power consumption in the MRAM. Recently, CIMS has been observed in MgO-based magnetic tunnel junctions (MTJs) with CoFeB electrodes[2)]. Thehigher TMR ratio enable them to have lower critical current density (J_C) compared to AlO barrier MTJs. So far, observed intrinsic critical current density (J_{C0})[1)] was reduced to 2×10^6 A/cm^2 [2)]. However, this value is still higher than the required value (5×10^5A/cm^2) in MRAM application. Furthermore,a high speed (< 10 ns) writing case, the precession amplification process becomes dominant during the magnetization reversal while the thermal activation process is suppressed[3)]. Therefore the understanding of the reversal process in nanosecond region is very important in MRAM application. This paper shows the CIMS results in nanosecond region forMgO based MTJs and discuss the reversal process.

The stacking structure is Ta(5)/FeNi(10)/IrMn(10)/$Co_{75}Fe_{25}$(2)/Ru(0.85)/$Co_{40}Fe_{40}B_{20}$(3)/MgO(0.8)/$Co_{40}Fe_{40}B_{20}$(2)/Ta(3)/Ru(2) (thicknesses in nanometer) deposited onto athermallyoxidized Si wafer using UHV sputtering system. The multilayers were patterned by using electron beam lithography and Ar ion etching into elliptically shaped (110 nm x 240 nm, 110 nm x 330 nm) pillars. The electrode was patterned into a coplanar wave guide shape with a low capacitance which enabled fast pulse transmittance. The MTJs were annealed at 270°C for 1h under an applied field of 5 kOe. The tunnel magnetoresistance (TMR) ratio measured using a four probe method was 115% and the MR curve showed a mono domain like shape. The CIMS measurement was carried out using a two probe method. Current-Resistance (*I - R*) measurement using 20 ns pulse duration showed a sharp resistance transition, which value is consistent with the change between resistances in parallel and anti-parallel magnetization configurations observed inMR measurement. Fig. 1 shows switching current (I_C) plots as a function of $ln(\tau_p/\tau_0)$ from 2 ns- to 100 ms-pulse duration. For 50 ns - 100 ms region, I_C shows linear change as $ln(\tau_p/\tau_0)$ and is fitted well to the thermal activation model. While for 2 ns- to 10 ns-pulse, the data can be fitted well to the precession model[3)]. Obtained I_{C0} = 1.7 mA (J_{C0} = 6.0×10^6 A/cm^2) from fitting to the precession model was the same with that from fitting to the thermal activation model[3)]. With an external field, I_C changed depending on the field direction, which is consistent with the expected behaviour from the potential energy change. These results suggest that the IC could be reduced by controlling of an initial angle distribution.

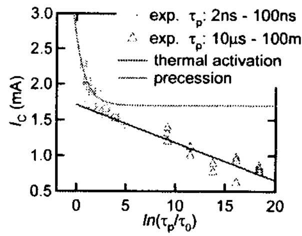

Fig. 1. I_C as a function of $\ln(\tau_p/\tau_0)$.

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