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Fabrication of Magnetic Tunnel Junctions with superparamagnetic CoFeB free layer

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Magnetic tunnel junctions (MTJs) with crystalline MgO(001) barrier have been studied intensively for the application of highly sensitive magnetic field sensors. Magnetoresistance (MR) curves with both linear and hysteresis-free shapes are required for magnetic field sensors. Recently, it has been found that ultra-thin CoFeB free layers realized linear and hysteresis-free MR curves because of their superparamagnetism. In addition, superparamagnetic free layers can reduce 1/*f* noise in the MTJs due to the reduction of fluctuation of domain wall motion [1)]. However, sensitivity in the MTJs with superparamagnetic free layers was not large. In this work, we have systematically investigated CoFeB free layer thickness and annealing temperature dependence of TMR effect to obtain MR curves with linear, hysteresis-free shapes and high sensitivity by optimization of superparamagnetism in the CoFeB free layers.

The stacking structure of MTJ films was Si/SiO_2-sub/Ta(5)/Ru(10)/Ta(5)/CoFe(2.16)/IrMn(10)/$Co_{75}Fe_{25}$(3)/Ru(0.9)/$Co_{40}Fe_{40}B_{20}$(2)/MgO(1.25)/$Co_{40}Fe_{40}B_{20}$(*d*)/Ta(5)/Ru(5) (in nm). The films were deposited by magnetron sputtering (P_{base} < 3.0 x 10^{-6} Pa). The magnetic easy axis of the ferromagnetic layers was induced by applying 100 Oe magnetic field during deposition. MTJ devices with the size of 10 x 20 μm^2 were fabricated by standard photolithography and Ar ion milling. The MTJ devices were annealed at various temperatures (from 365 to 385^{o}C) in high vacuum for 1 h applying magnetic field of 10 kOe. The TMR properties were measured at RT by using the DC four-probe method.

We found that superparamagnetic property of CoFeB was very sensitive to both their thickness and annealing temperature. Fig. 1 shows a MR curve in the optimized MTJ with 1.6 nm thick CoFeB free layer annealed at 375^{o}C. The MR curve showed the linear and hysteresis-free shapes at low magnetic field region and a large sensitivity of 10.5 %/Oe due to the superparamagnetism of the CoFeB free layer. This work was supported by the S-Innovation program, Japan Science and Technology Agency (JST).

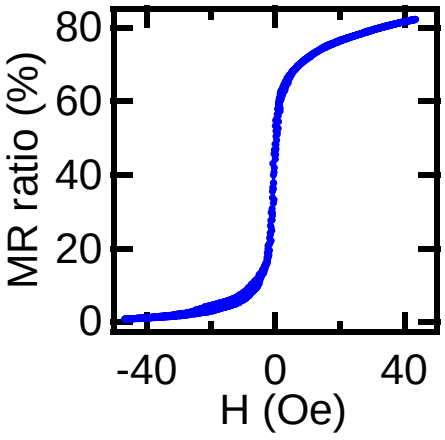

Fig. 1 MR curve in the MTJ with 1.6 nm thick CoFeB free layer annealed at 375^{o}C.

1) W. F. Egelhoff *et al.*, Sens. Actuators, A, vol. 155, pp. 217-225, 2009

2) Jiangwei Cao *et al.*, Applied Surface Science 314 (2014) 443-446