Tunnel magnetoresistance sensor devices with amorphous CoFeBTa-based free layers

NIMS °Mahmoud Rasly, T. Nakatani, J. Li, H. Sepehri-Amin, H. Sukegawa, Y. Sakuraba
E-mail: RASLY.Mahmoud@nims.go.jp

Tunneling magnetoresistance (TMR) devices based on CoFeB/MgO/CoFeB magnetic tunnel junctions (MTJs) sensors have exhibited potential for low magnetic-field sensing applications [1]. To improve the magnetic field sensing performance of those devices, the CoFeB free layer (FL) is often laminated with soft-magnetic materials such as NiFe [2]. However, the lamination of NiFe above/below CoFeB tends to degrade the TMR ratio because the 111 texture of NiFe propagates to the CoFeB layer. As alternative soft-magnetic materials for TMR sensors, amorphous soft magnets with higher crystallization temperatures than that of CoFeB (~300 °C) is important.

In this study, we introduced an amorphous $(Co_{0.4}Fe_{0.4}B_{0.2})_{91}Ta_9$ (CFBT) in the FL of a top-pinned spin-valve MTJ; (from substrate side) Ta (5)/Ru (10)/Ta (5)/Ru (10)/Ta (5)/CFBT (20)/Ta (0.3)/CoFeB (3)/MgO (2)/CoFeB (2.5)/CFBT (0.6)/CoFe (0.5)/Ru (0.8)/CoFe (3)/IrMn (8)/Ru (8) (nominal thickness in nm). We confirmed that the CoFeB free and reference layers have been crystallized by annealing at 350 °C, whereas CFBT was kept amorphous.

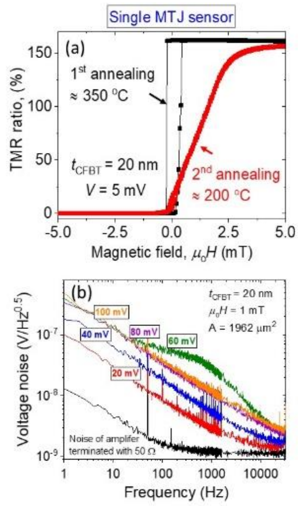

Fig. 1: (a) Transfer curve measued after 1st - & 2nd annealing. (b) Bias voltage dependence of voltage noise of a single MTJ sensor.

To obtain linear *R-H* transfer curves, we applied two-step annealing technique [1, 2]. Fig. 1(a) shows the transfer curves of MTJ sensor patterned to a 50 μm circular shape. By annealing at 350 °C under application of external magnetic field *H*, the device showed a square *R-H* curve with a coercivity ~0.5 mT. Thereafter, the same device was annealed again at 200 °C under an in-plane 90° rotated field. This resulted in a formation of orthogonal magnetizations between the free and reference layers, providing a linear *R-H* curve with a negligible coercivity, suitable for magnetic field sensors.

Fig. 1(b) shows the bias voltage dependence of voltage noise ($\sqrt{S_V}$) of the MTJ sensor in the linear *R-H* regime ($\mu_0 H \approx +1$ mT). A typical 1/*f* noise characteristics was observed for all V_b except at 60 mV, where random telegraph noise (RTN) was observed. As $\sqrt{S_V}$ scales linearly with V_b, the magnetic field detectivty (*D)* showed almost constant value of 2 nT/$\sqrt{\text{Hz}}$ at 10 Hz regardless of V_b, which is smaller than the reported value for a similar MTJ sensor with an amorphous $Co_{70.5}Fe_{4.5}Si_{15}B_{10}$ based FL (4.5 nT/$\sqrt{\text{Hz}}$ at 10 Hz) [2]. We also fabricated a full Wheatstone bridge sensor consisting of four identical TMR array sensors (A_1, A_2, A_3 and A_4), as shown by schematic in Fig. 2. Each array consists of 50-serial MTJs, each of which was patterned to a 30 μm circular shape. The bridge showed a linear output voltage *vs*. magnetic field response between –1.4 mT and +1.4 mT and $D \approx 600$ pT/Hz$^{0.5}$ has achieved at 5 Hz and V_b = 1V.

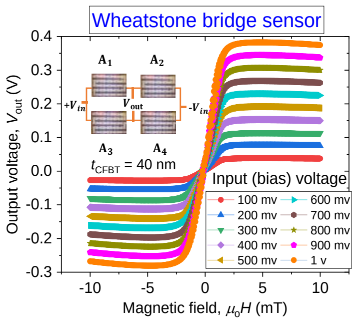

Fig. 2: Output voltage of the full Wheatstone bridge sensor at different bias voltages.

References

[1] A. V. Silva *et al.*, Eur. Phys. J. Appl. Phys. **72**, 10601 (2015). [2] L. Huang *et al.*, J. Appl. Phys. **122**, 113903 (2017).