Highly sensitive MTJ arrays with amorphous CoFeSiB for bio-magnetic field sensor

°S. Cakir, D. Kato, K. Fujiwara, H. Naganuma, M. Oogane, and Y. Ando (Tohoku Univ.)

E-mail: scakir@mlab.apph.tohoku.ac.jp

The magnetoencephalogram (MEG) is measurement of magnetic fields which is produced by electrical activity of brain. Such very small field (ca. hundreds of femto tesla) can be measured outside the head only by SQUID. Tunnel magneto resistive (TMR) sensors are promising candidates to replace SQUID with their recent development. TMR sensors work with low energy consumption and at room temperature environment with desired magnetic field sensitivity. Highly sensitive MTJs (over 100%/Oe) are needed to detect bio-magnetic fields. In recent studies, we achieved 40%/Oe in MTJs with amorphous CoFeSiB ferromagnetic electrodes [1]. However, MTJ arrays are needed to reduce $1/f$ noise and obtain enough signal-to-noise ratio [2]. In this study, we fabricated single, 10x10 series connected and parallel/series connected arrays of MTJs with soft CoFeSiB electrodes to expect noise profile improvement and high sensitivity.

Film deposition was performed in multi target ultra-high-vacuum (UHV) system with $P < 3\text{x}10^{-6}$ Pa base pressure. The thin film stacking was deposited on Si/SiO_2 wafer with magnetic field assistance as Ta(5)/Ru(10)/Ta(5)/CoFeSiB(x)/Ru(0.4)/$Co_{40}Fe_{40}B_{20}$(3)/MgO(1.8)/$Co_{40}Fe_{40}B_{20}$(3)/Ru(0.9)/$Co_{75}Fe_{25}$(5)/$Ir_{22}Mn_{78}$(10) /Ta(5)/Ru(8) where x is 70, 100 (in nm). MgO thickness was chosen for lower resistance compared to previous results [1] which is required for finer noise measurement. MTJs were fabricated with conventional micro-processes such as photo lithography and Ar ion milling. SiO_2 insulation was deposited at 280°C by CVD. Junction area of every MTJ was 31x31um^2. MTJs were annealed two times in vacuum furnace under 1T magnetic field on easy axis and orthogonal to easy axis to obtain hysteresis free TMR response. Magneto-resistance curves were measured by PC controlled DC 4 probe system.

Figure 1 shows first annealing temperature dependences of TMR ratio and H_c for single MTJ with 70nm thick CoFeSiB (CFSB) electrode. High TMR ratio over 200% and very small H_c were obtained at optimized annealing temperature of 350°C. In Fig. 2 and Fig. 3, TMR responses are given for single and 100 series connected array MTJs after second annealing at 325°C. For the single MTJ, hysteresis-free and highly sensitive TMR curve was observed after second annealing. On the other hand, for the array MTJs, H_c increased and sensitivity was small compared to single MTJ, although TMR ratio was over 200%. It may due to the distribution of magnetic properties of each device in the array MTJs. We will also present noise properties in the array MTJs. This work was supported by S-Innovation program, Japan Science and Technology Agency (JST).

[1] D. Kato *et al.*, Appl. Phys. Express **6,** 103004 (2013)

[2] M. Tondra *et al.* J. Appl. Phys. **83**, 6688 (1998).

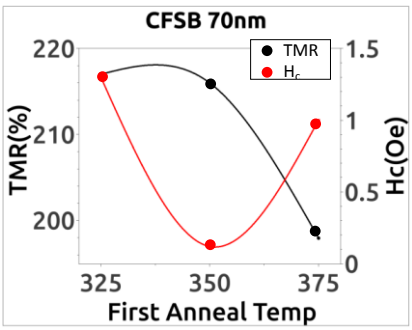

Fig. 1 First annealing temperature dependence of TMR and H_c in single MTJ

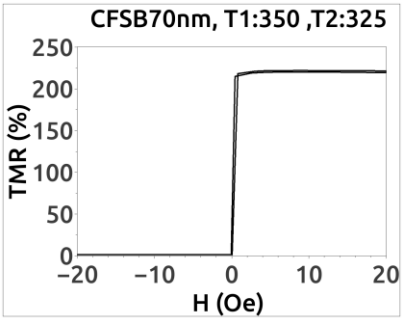

Fig. 2 TMR response of single MTJ annealed at 350°C as first and at 325°C

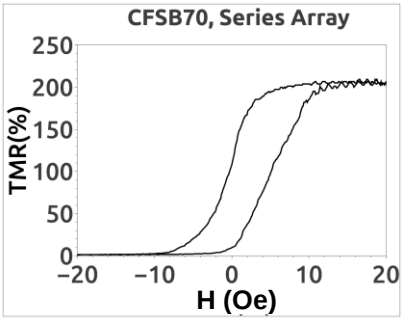

Fig. 3 TMR response of 100 series connected array MTJ annealed at 350°C as first and at 325°C