Signal-Noise Ratio Improvement of Magnetic Tunnel Junctions for Detection of Bio-Magnetic Field

K. Fujiwara[1], M. Oogane[1], D. Kato[1], J. Jono[2], H. Naganuma[1], M. Tsuchida[2] and Y. Ando[1]
[1]Department of Applied Physics, Graduate School of Engineering, Tohoku University,
Aoba-yama 6-6-05, Sendai 980-8579, Japan
[2]KONICA MINOLTA, INC., Tokyo, Japan

The discovery of large tunnel magneto-resistance (TMR) effect at room temperature in magnetic tunnel junction (MTJ) has spurred intensive investigation of MTJ applications for spin-electronics devices, such as magnetic random access memory and various magnetic field sensors. For sensor applications, low power consumption and small device size of MTJ make them prime candidates for next generation magnetic field sensor. In addition, from the feature that operate at room temperature, MTJ enables detection of bio-magnetic field (e.g. magnetocardiogram (MCG), magnetoencephalogram (MEG)) without liquid He (Fig.1). However, sensitivity and noise reduction are insufficient in MTJs have been developed. In this work, we fabricated MTJ with antiferromagnetic coupled bottom free layer for high sensitivity, and MTJs were connected series-parallel to reduce noise.

MTJ films were deposited on to thermally oxidized Si (001) wafers using DC/RF magnetron sputtering system. MTJs were micro-fabricated by photolithography process and Ar-ion milling. After micro-fabrication, MTJs were annealed 260 - 350 °C with applied magnetic fields of various directions. Fig.2 shows *R-H* curves of MTJ with CoFeSiB/Ru/CoFeB antiferromagnetic coupled free layer. High sensitivity of 115%/Oe was observed in single MTJ[1]. Fig.3 shows a schematic image of signal and noise measurement. Series-parallel connected MTJs were placed in the center of the Helmholtz coil, the output voltage was amplified by the 100 dB amplifier and input to the oscilloscope. Fig.4 shows MgO barrier thickness dependence of signal voltage, noise voltage and S/N ratio measured from 18 Hz, 120 $nT_{p\text{-}p}$ input magnetic field. Both signal and noise decreased with decreasing MgO thickness. From this relation of signal and noise, maximum 154 S/N ratio was acquired by 2.2 nm MgO thickness. The Detectivity *D* (*D* = noise/signal) of MTJs with 2.2 nm MgO barrier was 0.8 nT, this value is possible to measure cardiac magnetic field by performing integration of the order of 100 times.

Acknowledgment This work was supported by the S-Innovation program, Japan Science and Technology Agency (JST) and Center for Innovative Integrated Electronic Systems, Tohoku University.

Reference 1) D. Kato *et al.*, APEX, **6** (2013) 103004.

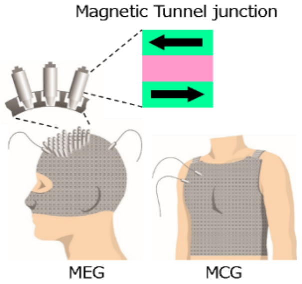

Fig.1 Schematic image of bio-magnetic field sensor using magnetic tunnel junctions.

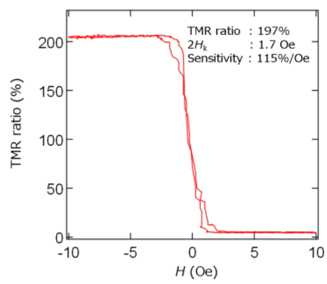

Fig.2 *R-H* curve of MTJ with CoFeSiB/Ru/CoFeB synthetic coupled free layer.

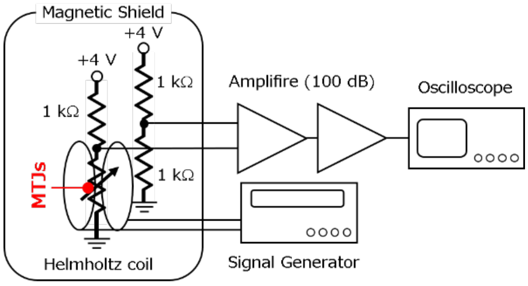

Fig.3 Schematic image of signal and noise measurement system.

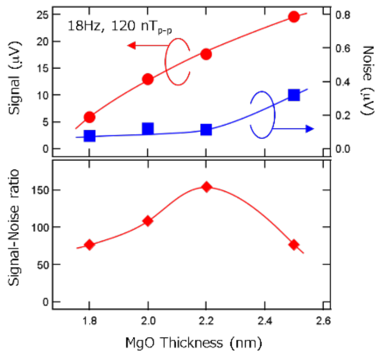

Fig.4 MgO barrier thickness dependence of signal voltage, noise voltage and