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Magnetic tunnel junctions for bio-magnetic field sensor

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The discovery of large tunnel magneto-resistance (TMR) effect at room temperature (RT) in magnetic tunnel junctions (MTJs) spurred intensive investigation of MTJ applications for spintronics devices. For sensor application, high sensitivity, low power consumption, small device size and low cost make it prime candidate of the next generation magnetic field sensor such as a bio-magnetic field sensor [1, 2]. It needs individual MTJs with a large sensitivity over 10%/Oe and 100 x 100 integrated MTJs to achieve enough output signal and S/N ratio. Here, sensitivity is defined as TMR-ratio/2H_k, where H_k is anisotropy field of the free layer. In this work, we demonstrated a sensor module enough to detect a small signal from heart.

The MTJs were deposited on thermally oxidized Si(001) wafers by using an ultrahigh vacuum (P_{base} < 3 x 10^{-6} Pa) magnetron sputtering system. The stacking structure was Sub. /Ta (5)/Ru (10)/Ta (5)/$Ni_{80}Fe_{20}$ (70)/Ru (0.9)/$Co_{40}Fe_{40}B_{20}$ (3)/MgO (2.5)/$Co_{40}Fe_{40}B_{20}$ (3)/Ru (0.9)/$Co_{75}Fe_{25}$ (5)/$Ir_{22}Mn_{78}$ (10)/Ta (8) (in nm). A single MTJ was micro-fabricated by using the photolithography process and Ar-ion milling. 100 MTJs were connected in series and then in parallel by top electrodes. The eventual size of the array of the 100 x 100 MTJs was 7 x 7 mm^2. After micro-fabrication, the MTJs were annealed several times. In the optimal condition, each easy axis of the bottom free and the top pinned layers became orthogonal. The 100 x 100 integrated MTJs were connected to a bridge circuits, and an output voltage was fed into a home-made low noise amplifier with a gain of 123,000 (Fig. 1). We investigated the ability to detect an imperceptible magnetic field by using the module. In order to show the signal detection capability nearer to a bio-magnetic field, what measured the heart waveform would be made into a reference signal (Fig. 2 (a)), and a waveform could be reproduced with the module by making the false magnetic field waveform reproducing this into an input signal. The amplified output signal was digitized by using a vector signal analyzer (Fig. 2 (b)). The reproducing shape has the characteristic peaks in the original signal; the homemade TMR sensor module is promising to detect the real bio-magnetic field from a heart. This work was supported by S-Innovation program of JST. [1] K. Fujiwara *et al.*, Jpn. J. Appl. Phys., **52**, 04CM07 (2013). [2] D. Kato *et al.*, Appl. Phys. Express, **6,** 103004 (2013) .

Fig. 1. Module with the 100 x 100 integrated MTJs connected to a bridge circuit and low noise amplifier.

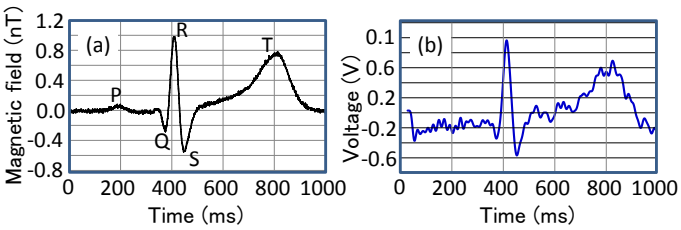

Fig. 2. (a) Reference signal which wave form is reproduced from a heart signal, (b) and amplified sensor output.