Measurement of biomagnetic information using room temperature operation tunnel magneto-resistance sensor

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The tunnel magneto-resistance (TMR) sensors using magnetic tunnel junctions (MTJs) are expected as highly sensitive magnetic sensors operating at room temperature. Magnetic sensors are used for current sensing, displacement / rotation sensing, nondestructive testing, *etc*., and in recent years, biomagnetic field measurement that senses the activity of the human body with a magnetic field has been actively studied. Measurement of biomagnetic field includes magnetocardiography (MCG)[1)] resulting from electrical activity of the heart and magnetoencephalography (MEG)[2), 3)] measuring brain current. These magnetic field measurements are considered to be useful tools for medical diagnosis and basic research because they have high spatial resolution and temporal resolution compared to electrical measurements.. On the other hand, since the biomagnetic field is a very weak magnetic field of at most 100 pT, the sensors that can perform the measurement are limited.

We have been researching to realize the measurement of this biomagnetic field using a TMR sensor. Until now, we have succeeded in partial real-time MCG measurement using a TMR sensor and MEG measurement using averaging[4)]. The MTJ multilayer film used for the TMR sensor was deposited by ultra-high vacuum sputtering system. This multilayer film is characterized in that it has MgO barrier layer and has a synthetic structure using $Ni_{80}Fe_{20}$ in the bottom free layer. Since it was necessary to reduce the noise of the TMR sensor in order to measure a small magnetic field, we reduced 1/*f* noise by arranging a large number of MTJs in an array. The size of the fabricated MTJ array was 7.1×7.1 mm^2, and four arrays were used to construct a bridge. The output from the TMR sensor bridge was amplified and filtered and measured by a PC using an A/D converter. In MCG, the R-peak caused by the heartbeat was measured with a probability of about 1/2, and a clear QRS wave was measured by performing averaging about 16 times. Moreover, MEG succeeded in measuring the 10 Hz magnetic signal originating from the α wave by averaging 10,000 times, and confirmed that the phase of the signal is rotated 180 degrees by rotating the direction of the TMR sensor by 180 degrees. At present, we are studying to improve the multilayer film structure of the TMR sensor to further increase the sensitivity. There is a method of thinning the MgO barrier layer to reduce the noise of the TMR sensor. At this time, when the resistance value of the junction decreases, the signal is reduced due to the parasitic resistance of the lower electrode film. As a countermeasure against this parasitic resistance, a thick Cu film was deposited and a chemical mechanical polishing process was performed, and a TMR multilayer film was formed on this substrate to reduce the resistance. In addition to the improvement of the multilayer film structure, we are also examining the improvement of signal and noise by changing the spatial arrangement of the TMR sensor. In addition to the feature of room temperature operation, TMR sensor has the feature of wide magnetic dynamic range, and its output does not saturate even if it is used in geomagnetism. Therefore, it is thought that operation outside the shield room is also possible. Using this feature of wide dynamic range, we are currently studying for measuring biological information without a shield room.

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