Investigation of serial magnetic tunnel junction sensors for high signal-to-noise ratio in eddy current testing

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In recent years, magnetic tunnel junctions (MTJs) based on MgO barrier have been attracted considerable interest due to high tunnel magneto-resistance (TMR). An earlier study reported that TMR sensor based on MTJ can detect small field change, which indicated these devices can be used in eddy current nondestructive testing (ECT) field [1]. However, it is still required to develop a sensor for detection of different defects. Considering that adding serial MTJ number in the sensor can improve sensitivity [2], an optimized serial TMR sensor can provide a high signal-to-noise ratio (SNR) during ECT. Therefore, for achieving high SNR, we fabricated sensor with 4, 16, 28, and 40 serial MTJs in 1, 4, 7, and 10 rows, respectively. Furthermore, we investigated their detectivity and analyzed their output signals to determine the maximum SNR for detection of different defects in ECT.

The magnetic film structure of MTJ was SiO_2-sub./Ta(5)/Ru(10)/Ta(5)/$Ni_{80}Fe_{20}$(70)/Ru(0.9)/$Co_{40}Fe_{40}B_{20}$(3) /MgO(2)/$Co_{40}Fe_{40}B_{20}$(3)/Ru(0.9)/$Co_{75}Fe_{25}$(5)/$Ir_{22}Mn_{78}$(10)/Ta(8) (in nm). These series of 4, 16, 28, and 40 MTJs with $10\times10\mu m^2$ top pinned layers and $15\times60\mu m^2$ bottom free layers were fabricated with photolithography and ion milling processes. After fabrication, for achieving excellent R-H curve, the fabricated MTJs were annealed twice in a vacuum chamber using different directions and temperatures [3]. Furthermore, automatic ECT system was composed of an excitation unit with a function generator which delivers excited signal and sensing probe with the prepared MTJ device. The surface and back-side pits with various regimes in aluminum and copper specimens were inspected by using ECT probe with TMR sensors.

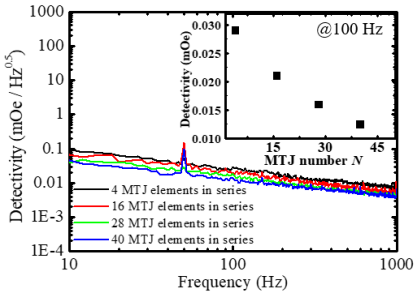

Fig.1 Detectivity for different sensors at different frequencies. Inset: dependence of detectivities on serial MTJ numbser N at excitation freuqneyc of 100 Hz.

Figure 1 showed the dependence of detectivity of the sensor on serial MTJ number N. It is indicated that the TMR sensor with a large MTJ number can offer small detectivity. However, since the inhomogeneous secondary field induced from eddy currents in the specimen, the disturbance of field strongly affected by the distance between individual MTJ and test specimen during defect detection. As shown in Figure 2, the ECT result when different sensors were used to detect a surface crack, the noise amplitude increases with the number of serial MTJs, which indicates the dependence of noise on their number. On the other hand, due to the distribution of secondary field, the crack signal reached a saturation for N =28, and highest SNR can be obtained. Although the inner defects of the copper specimen were inspected, the probe with TMR sensor (N = 28) offered considerable high SNR. This study suggested that the optimized TMR sensors can play an important role in achieving high SNRs during ECT.

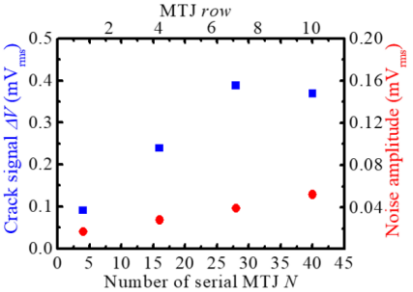

Fig.2 The relationship between amplitude of the crack-free signal and noise during surface inspection with different sensors.

Reference

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