고집적 MRAM 개발을 위한 요소기술

(Issues for high density MRAM)

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1. Introduction

Key attributes of MRAM technology are known as non-volatility with high speed and density, radiation hardness, unlimited endurance. A lot of results have been announced for commercial market. And it is anticipated that MRAM will play an important role in future memory market through its unique, functional advantages. For high density MRAM as a standalone memory, several issues related with MRAM core cells should be preferentially solved. The topic will cover basic issues of sub-micron MRAM core cell and consider the work related to the MRAM issues, such as cell stability and switching process.

2. Main Issues of sub-micron MTJ core cell for high density MRAM

Successful demonstration by the previous work ensures that MRAM technology is a strong candidate of universal memory among the other new memory technologies with the comparison topics such as power consumption, speed, scalability, retention, endurance, and density. However there are still some fundamental issues to attain the real memory device for high density.

2.1) Resistance uniformity of Sub-micron MTJ cell

To accomplish high density MRAM, the precedent technology is the fabrication of sub-micron MTJ cell array which is sensitive to the cell design and the fabrication process. For the fabrication, deposition and etching of the MTJ are most critical processes. Uniformity and control of the deposited layer thickness are directly related to the sensing margin. The uniformity of the resistance, which comes from the uniformity of the tunneling barrier (typically, Al_2O_3) thickness, is extremely important since it should distinguish the data-0 and 1 with only less than 50% of the resistance difference and the resistance is determined by the barrier thickness.

2.2) The effect of bottom electrode to sub-micron MTJ cell stability.

The bottom electrode is also an important factor to determine the properties and electrical stability of MTJ cells, such as high MR, resistance uniformity, high breakdown voltage, and good bias dependency of MR. The effect of bottom electrode is mainly due to the roughness of bottom electrode. The observed degradation with respect to the roughness of bottom electrode was thought to be from the increase of local defects such as pin-holes or local weak point in non-uniformly oxidized aluminum oxide. Since the minimal variation of RA and high MR ratio at suitable bias are crucial factors for the stable sensing signal in MRAM, maintaining smoother surfaces of bottom electrode is needed. As surface roughness decreases, the MR and resistance increase.

2.3) Switching process in sub-micron MTJ cell

In a MRAM array, a cell is selected for data writing by two orthogonal magnetic fields that are simultaneously generated from the current lines. Due to this half-selection rule, sharp switching in MR curve is necessary to obtain acceptable selectivity. If there are any metastable states of local magnetic moment distribution on the free layers, either large switching field or selection fail will be resulted.

The metastable states are called 'kink'. The kink in MR curve is originated from vortex or domain wall pinning/dragging[1][2] that is strongly correlated with cell shape and saturation magnetization of free layer. The switching process of sub-micron MTJ cell ,related with kink, are extremely important and are directly related to the writing current margin due to the asteroid distribution. Fig. 1 and Fig. 2 show the bit distributions of 8x9 arrays before cell optimization (with kink) and after cell optimization (without kink), respectively. The array with kink has many fail bits at low and high field. On the other hand, The array without kink has no fail bits at low and high field. All bits in the array without kink are switched at less than 10 mA.

3. Conclusion

The purpose of this study is to test the fundamental technology limit for an actual memory device. Research scope was restricted to only core cell at this stage. After success demonstration of integration process of MTJ and MOS transistor as a core cell unit, our facilities are ready to test the MRAM technology. The key issues of MRAM technology as a future memory candidate are uniform resistance and switching control for sub-micron or deep sub-micron device size. Resistance and MR are limited by the uniformity of barrier thickness induced by bottom electrode. Switching issues are controllable with a choice of appropriate shape and fine patterning process.

Finally it should be pointed out that controls of fabrication is rather important to realize an actual memory device for MRAM technology

4. References

[1] J. Shi, S. Tehrani, T. Zhu, Y. F. Zheng and J.-G. Zhu, "Magnetization vortices and anomalous switching in patterned NiFeCo submicron arrays", Appl. Phys. Lett., vol.74, pp. 2525, 1999.

[2] J. Shi and S. Tehrani, "Edge-pinned states in patterned submicron NiFeCo structures", Appl. Phys. Lett., vol.77, pp.1692, 2000

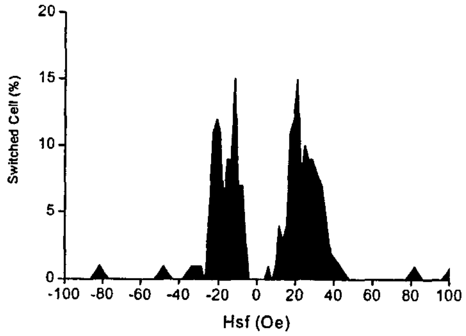

Fig. 5 bit distributions of 8x9 arrays before cell optimization (without kink)

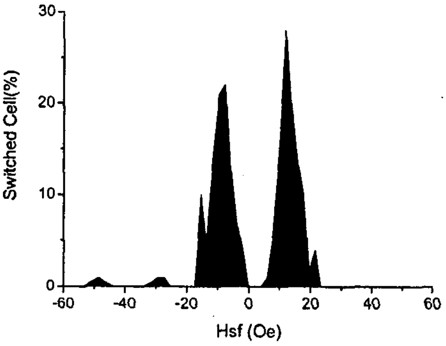

Fig. 6. bit distributions of 8x9 arrays after cell optimization (with kink)