Proposal and Analysis of the MRAM with Pole Type System by Using Hysteresis Modeling

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Abstract — In this paper, new MRAM designs for high Gb/Chip with pole system was introduced. In order to overcome problem of reducing power consumption, we proposed new MRAM design that has two additional high permeable poles. Proposed new MRAM designs has a strong switching field owing to two poles added on both sides of the free layer, just like perpendicular magnetic recording heads. In this paper, new efficient algorithm to combine two models are presented and tested. This approach reduces computing time and gives more precise results because the result of 2 dimensional Preisach model becomes an initial values of 3 dimensional micromagnetics. And vectorial magnetization with time dependent magnetization could be also included in this model.

I. INTRODUCTION

MRAM has the potential to be competitive with all existing semiconductor memories and, through its unique properties, provide new functionalities. The key attributes of MRAM technology are non-volatility combined with high-speed operation and effectively unlimited read-write endurance[1]. Conventional (toggle) MRAM has unlimited read/write endurance but has a low capacity than flash technology. Partly because conventional MRAM has a faulty structure using a simple write current injection system.

A lot of work has been done for the commercialization of submicrometer MRAM in recent years. A low-power 1–Mb MRAM with copper interconnects and cladding layer, and about 35 ns access and cycle times tested in the previous work show the potential of this technology[2]. A new multibit MRAM cell of toggle switching type has been reported[3] and also, a heat interaction investigation in thermally assisted MRAM has been reported[4].

The easiest way within the capability of today's thin-film technology is to have an intrinsic magnetic easy axis perpendicular to film plane [5], which should be the main contribution to the switching field threshold [6] .

In order to solve the problem that has the MRAM, this paper proposed the new MRAM system. Proposed MRAM design has two additional high permeable poles. We added a pole type is call pole system. By the added pole, conventional MRAM or STT MRAM can increase strong switching field and decreasing injection current. In this paper, we present a various MRAM design by using pole system. This paper show results that are variation of a switching field owing to two poles added on both sides of the free layer by thickness of the free layer and cell square size with injected current density of $5\times10^{6}\,A/cm^{2} \sim 6\times10^{8}\,A/cm^{2}$. This approach reduces computing time and gives more precise results because the result of 2 dimensional Preisach model becomes an initial values of 3 dimensional micromagnetics.

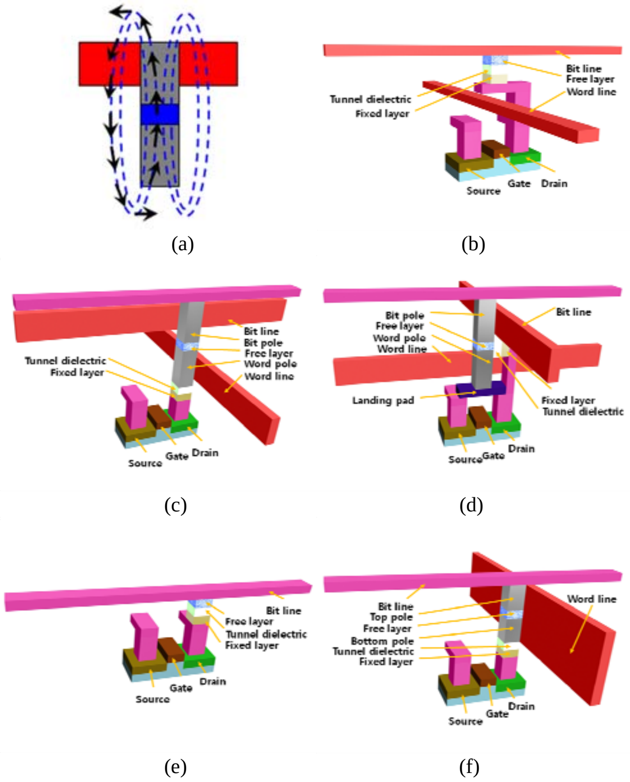

Fig. 1 Schematic drawing of the various MRAM elements. (a) Schematic drawing of the pole system. (b) conventional MRAM (c) PTP MRAM (d) SJP MRAM. (e) STT MRAM. (f) PTSTT MRAM.

II. PROPOSED MRAM SYSTEM WITH POLE TYPE SYSTEM

Fig Fig. 1 shows a schematic drawing of the various MRAM elements. Fig.1 (a) is pole system. Pole system has a strong switching field owing to two poles added on both sides of the free layer, just like perpendicular magnetic recording heads. (b)~(f) is schematic drawing of the MRAM system with pole type system. On the pole system, for magnetization of memory cell, we used the finite element micromagnetic approach. Only the storage-layer stack, consisting of a relatively thicker layer with perpendicular anisotropy and a thin soft magnetic layer, is modeled. The interlayer exchange coupling is assumed to be 30e-12 J/m. The perpendicular anisotropy constant of the thicker layer is assumed to be K_u = 10e3 J/m^3 and the fixed layer is assumed to be K_u = 10e4 J/m^3.

Write process of proposed the MRAM system has that is like the fig 2. SJP MRAM used applied switching field from bit and word line. Figure 2 shows write process of the SJP MRAM. When system require to change status of the memory, on the SJP MRAM system, status of the memory magnetization is changed by applied switching filed from bit and word line as like a fig 2 (a). As a result, SJP MRAM system stably has a changed the memory status.

III. Results and Discuss

One cell square size is 50 nm (W) X 50 nm (H), fixed layer thickness is 30 nm, and pole length is 400 nm. We changed free layer thickness for stronger switching field from 30 nm to 10 nm. Fig. 3 shows a result of the 5 by 5 cell model. Write process of the dual current type clearly shows the perfect results that the target cell can be switched and the other cells retain their memory status, for the switching field intensity at the target cell is 672.11 Oe, and are 210 ~ 250 Oe at the other cells. From the simulation results, we know that pole system is useful for high capacity, having downsize scalability with even higher coercivity free layer than in MRAM. On the pole system, for magnetization of memory cell, we used the finite element micromagnetic approach. Only the storage-layer stack, consisting of a relatively thicker layer with perpendicular anisotropy and a thin soft magnetic layer, is modeled. The interlayer exchange coupling is assumed to be 30e-12 J/m. The perpendicular anisotropy constant of the thicker layer is assumed to be K_u = 10e3 J/m^3 and the fixed layer is assumed to be K_u = 10e4 J/m^3. Fig. 5 shows the result of micromagnetic approach on SJP MRAM system. In these results, we can know that free layer is changed by applied switching field but fixed layer is not changed. Pole system is useful for high capacity, having downsize scalability with even higher coercivity free layer than in MRAM.

IV. Conclusion

In order to solve the problem of MRAM, this paper suggested pole system. Proposed pole system can be downsize scalability due to strong switching field for the high density. This paper was proof of the result of micromagnetic approach. As a result, MRAM with pole system issues from the current density that can provide clues to escape.

V. References

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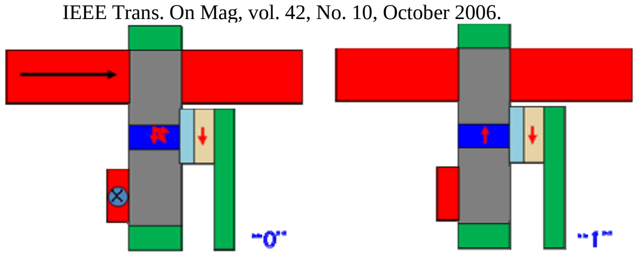

Fig. 2 Write process of the SJP MRAM (a) shows “0” status. When direct current is injected in bit and word line, status of free layer is changed like (b). Finally status of the free layer is stabilized to be “1”.

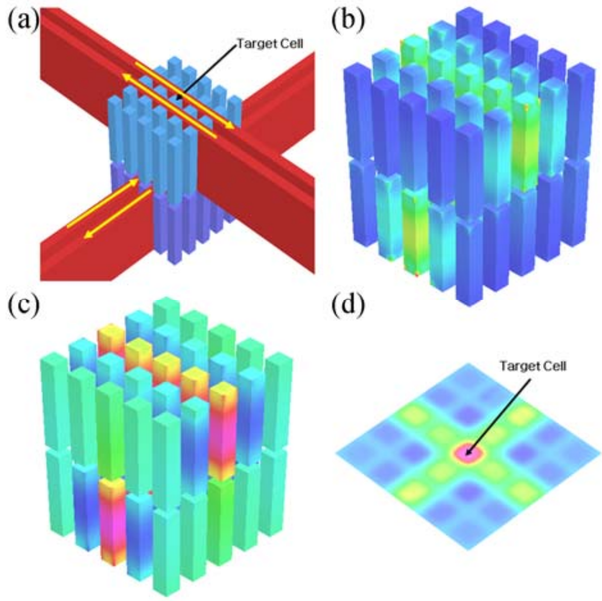

Fig. 3 Simulation results of the 5 by 5 multi-element model with the dual current type. (a) Using both bit and word line can toggle memory of the target cell; the other cells are not changed and stable. (b) |B| field distributions. (c) Hz field distributions. (d) Hz field distributions on the center of free layer.

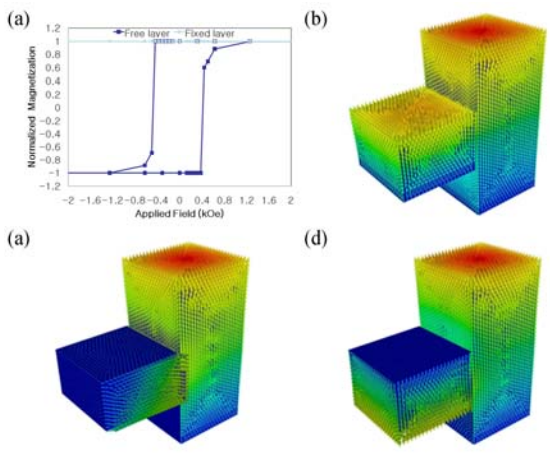

Fig. 4 Calculated magnetization switching under a directly injected current densities factor I $= -5\times10^6 A/cm^2 \sim 5\times10^6 A/cm^2$ on the free and fixed layer. (a) calculated hysteresis loops. (b) 0 ns. (c) 0.06 ns. (d) 0.15 ns.