Material dependence of the effect of SOT-MRAM read disturb reduction method

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1. Introduction

SOT-MRAM uses spin orbit interaction to control the magnetization of a memory cell. It is believed that because the read and write current paths are separated, the spin Hall effect that occurs during writing does not occur during reading. Therefore, separate optimization for reading and writing is possible. However, we previously reported that the spin Hall effect occurred during reading, which indicated a disturbance in the magnetization of the free layer, and proposed a new memory cell structure as a solution to reduce read disturb [1]. In this paper, we simulate our previously proposed memory cell structure in which the free layer and pinned layer are composed of a number of fundamental ferromagnetic materials (iron, cobalt, permalloy) and simulate the material dependence of the effect by the read disturb reduction .

2. Proposed SOT-MRAM memory cell to reduce read disturb

In SOT-MRAM, a disturb problem arises due to the spin Hall effect generated during reading. This is because the current flows in one direction in the horizontal direction in the heavy metal layer as shown in Fig. 1 (a). To solve this problem, we previously proposed that the same current should flow in the layer in both directions as shown in Fig. 1 (b) [1]. With this approach, reverse spin currents are generated in both direction by the spin Hall effect and cancel each other out, reducing read disturb.

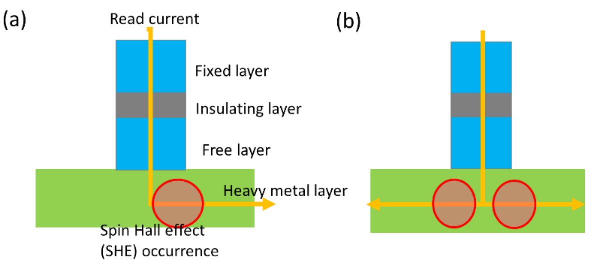

Fig 1 Read current path of memory cell magnetoresistive element
(a) Conventional structure (b) Proposed structure (disturb reduction)

3. Simulation contents

Material dependence of the effect of the proposed disturb reduction approach was investigated by simulation. For this purpose, the magnetic materials of the free layer and pinned layer were composed of three types of iron, cobalt, and permalloy and compared. The parameters of the materials are shown in Table 1. By using "LLG Micromagnetics Simulator," numerous iterations of the same operations at each condition were performed, and we obtained a relation between the amount of flowing current and the probability of reversing the free layer. The magnetoresistive element was formed into a four-layer structure consisting of a heavy metal layer (30 × 90 × 2.0 nm), a free layer (30 × 90 × 1.5 nm), a pin layer (30 × 90 × 1.5 nm), and an insulating layer (30 × 90 × 1.0 nm). Furthermore, the magnetization reversal probability after 10 years was obtained using the following equation.

$$P = 1 - \exp[-m\frac{t}{\tau_0}\exp\{-\frac{E}{K_BT}(1-\frac{I_R}{I_w})\}]$$

P is the reversal probability, I_R and I_w are read / write currents, τ_0 and t are the precession cycle (1 ns) and the cell current duration. E, K_B, and T are the energy barrier, Boltzmann constant, and temperature, respectively [2].

Table 1 Material parameters

	Iron	Permalloy	Cobalt
Saturation Magnetization Ms [emu/cm3]	1714	800	1414
Uniaxial Anisotropy K_u [erg/cm^3]	0	1000	4000000
Cubic Anisotropy K_C[erg/cm^3]	470000	0	0

4. Result

As shown in Fig. 2, comparing the conventional structure to the proposed structure with read disturb reduction, the magnitude of the magnetization reversal current becomes about 10 times larger for iron, about 10 times for cobalt, and about 45 times for permalloy. This indicates that our proposed structure could reduce read disturbance by an order of magnitude for all materials. The high magnitude in permalloy is due to its small magnetic anisotropy.

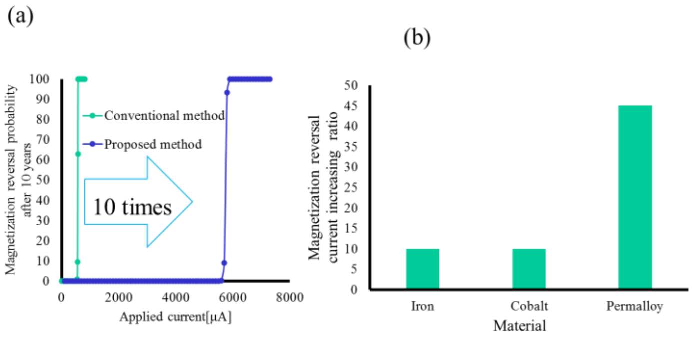

Fig 2 (a) Magnetization reversal probability of read disturb reducing memory cell in iron
(b) Magnetization reversal current increasing ratio

5. Conclusion

SOT-MRAM is expected to be developed as an ultra-low power consumption nonvolatile memory. The effect of the proposed SOT-MRAM disturb reduction approach was investigated by simulation on the dependence of three types of ferromagnetic materials, and the reduction ratio of more than one order of magnitude was shown for all materials. Therefore, this approach has been demonstrated to be useful to solve read disturbance for advancing SOT-MRAM.

References

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