High-Speed Motion Core Technology for Magnetic Memory

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Domain wall motion memory is a promising candidate for next generation memory, which has high-density, low-power, and non-volatility. However, previous studies showed the speed limit of domain wall motion memory to be hundreds m/s at maximum. Here we discovered that the use of 'ferrimagnetic' GdFeCo at angular momentum compensation point could overcome the speed limit and increase domain wall speed to over 2 km/s at room temperature. This research is significant in discovering a new physical phenomenon at the point in which the angular momentum of ferrimagnetic body is 0 and is expected to advance the implementation of next generation memory in the future.

1. Background

The currently used memory materials, D-RAM and S-RAM, are fast in speed but are volatile, leading to memory loss when power is switched off. Flash memory is non-volatile but slow, while hard disk drive (HDD) has large storage but high in energy usage and weak in physical shock.

To overcome the limitations of existing memory materials, 'domain wall-based magnetic memory' has been proposed. The core mechanism of domain wall magnetic memory is the movement of domain wall by the current (see figure in next page). Non-volatility is secured by using magnetic nanowire and the lack of mechanical rotation reduced power usage. However, previous studies showed the speed limit of domain wall memory to be hundreds m/s at maximum due to 'Walker breakdown phenomenon', which refers to velocity breakdown from angular precession of domain wall. Therefore, there was a need to develop the core technology to remove Walker breakdown phenomenon and increase speed for commercialization of domain wall memory.

2. Contents

Most domain wall memory studies used ferromagnetic body, which cannot overcome Walker breakdown phenomenon because it has 'intrinsic' angular momentum. The possible way to overcome the 'intrinsic' difficulty is to use antiferromagnetic body because it has zero angular momentum as a whole. However, experiment of antiferromagnet is very challenging because antiferromagnet is invisible and uncontrollable by an external magnetic field. In this study, we focused on the 'ferrimagnetic' GdFeCo. This material has antiferromagnetically coupled two sub-moments,

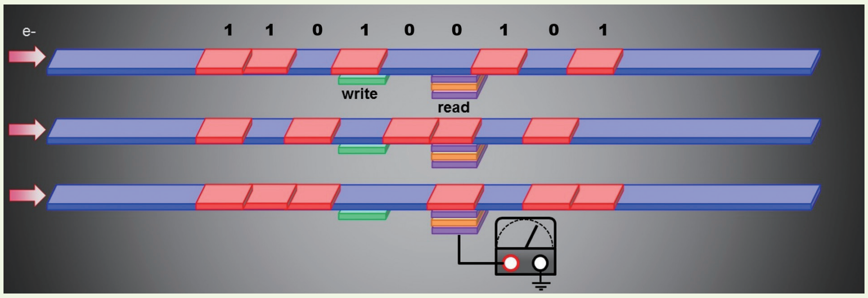

Fig. 1. Domain wall memory

that is, Gd and FeCo, so that it shows antiferromagnetic spin dynamics. Interestingly, this magnetic material has two special temperatures: the magnetization compensation temperature, T_M, at which the two magnetic moments cancel each other, and the angular momentum compensation temperature, T_A, at which the net angular momentum vanishes. In particular, the existence of T_A in ferrimagnets provides a possibility to suppress Waler breakdown phenomena. Furthermore, the finite magnetic moment at T_A can couple to an external field, opening a new possibility to control the antiferromagnetic dynamics.

To check this possibility, we investigated the magnetic domain wall speed across the T_A. As the temperature approaches to T_A, the domain wall speed rapidly increases and reaches its maximum at T_A. This result means that at T_A of ferrimagnets the Walker breakdown phenomena is indeed suppressed and high domain wall speed can be achieved due to the pure antiferromagnetic spin dynamics. By controlling the composition of Gd and FeCo, we further succeeded to obtain high speed of domain wall as high as 2 km/s near room temperature.

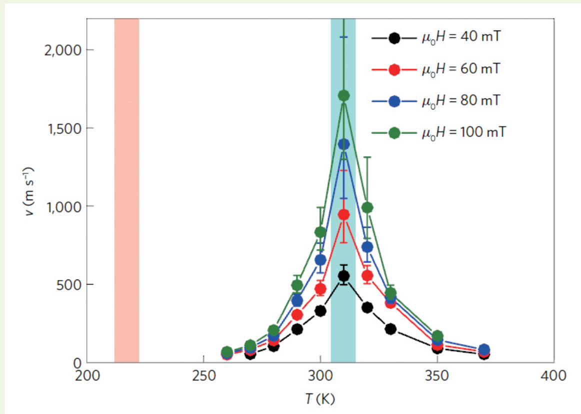

Fig. 2. Magnetic domain wall velocity across the angular momentum compensation temperature (T_A=310K) [Kim et al. Nat. Mater. 16, 1187 (2017)]

3. Expected effect

- (Technologically) Domain wall memory is high-density, low-power, and non-volatile memory. The memory could be the leading next generation memory with addition of high speed property discovered in this research.
- (Academically) This research discovered a new phenomena that occurs when the system angular momentum becomes zero, which will be a key to realizing antiferromagnetic and ferrimagnetic spintronics.

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Research Outcomes

- [Paper] Kab–Jin Kim et al, "Fast domain wall motion in the vicinity of the angular momentum compensation temperature of ferrimagnets", Nature Materials 16, 1187 (2017)
- [patents] Shift register and data shift method thereof, No : 10–2017–0110968