学位論文の要約

題目 Three-dimensional domain wall motion memory with artificial ferromagnet
（人工強磁性体を用いた三次元磁壁移動メモリの研究）

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序論

Domain wall (DW) motion memory is an emerging storage technology that had been proposed by IBM in 2008, which promises a highly reliable, and high storage density media for the surging requirements of data storage in the upcoming big data era. However, there are still some crucial problems pended and hamper the commercialization of DW motion memory. In this research, we propose a new type of DW motion device, named three-dimensional domain wall motion memory achieved by artificial ferromagnet. In the first research, we used the micromagnetic simulation to demonstrate the feasibility of our proposed device. According to the results, we conclude that this device can solve the major problems that traditional DW motion memory faced. In the second research, we found that the high thermal stability and low current driven properties can be simultaneously achieved in our proposed device. Our proposal provides a promising way to speed up the commercialization of DW motion memory.

1. <u>Low Current Driven Vertical Domain Wall Motion Memory with an Artificial Ferromagnet</u>

In this research, we propose a three-dimensional structure of a multi-bit DW motion memory cell, in which the vertical magnetic wire is composed of the periodically stacked bi-layers. The bi-layer comprises a strong coupling layer, which is named after its relatively strong magnetic exchange stiffness (A_{ex}), and a weak coupling layer, which shows relatively weak A_{ex}. The concept of this device is also proposed. Initially, the logic bit can be programmed into the lowest strong coupling layer by the spin-orbit-torque-induced switching, and causes the lowest weak coupling layer to become an artificial DW. To move the program bit inside the vertical magnetic wire, one can inject a series of current pulses to drive the spin-transfer-torque (STT)-induced DW motion. The strong coupling layer is aimed to carry the logic bit, and the weak coupling layer is to carry DW. We applied the simulation on MUMAX3, a micromagnetic analysis tool, to demonstrate the feasibility of our proposed device.

Based on the simulation results, we found it possible to tune the DW width with the A_{ex} of weak coupling layers. With the A_{ex} smaller than 3 pJ/m, we can obtain the DW width narrower than 3 nm. Besides, with the A_{ex} of weak coupling layers larger than 2 pJ/m, we can observe the J_c for DW motion down to 10^{10} A/m^2. The abrupt decreasing of J_c as A_{ex} increases from 1 pJ/m to 2 pJ/m can be attributed to the transition of magnetization in the weak coupling layer from vortex into a single-domain structure with high STT efficiency.

2. <u>High thermal stability and low driven current achieved by vertical domain wall motion memory with artificial ferromagnet</u>

In the last study, we proposed a three-dimensional DW motion memory with a vertical magnetic wire composed of periodically stacked bi-layers of strong and weak coupling layers. In our settings, the strong coupling layer is set with perpendicular magnetic anisotropy (K_u) while the weak coupling layer is not. In this research, we numerically demonstrated the current-driven properties, and the depinning field relative to the thermal stability in our device. Two major phenomenon was found in our proposed device. First, with the optimized current density and current pulse, it is possible to drive the DW motion while keeping the DW in the weak coupling layer, suggesting the position of DW can be precisely control. Second, by setting the K_u of strong coupling layer to around 10^6 J/m^3, a two-barrier system can be observed, indicating it is possible to achieve low J_c for DW motion around 10^{10} A/m^2 with high depinning field at the same time. The results suggest that, with the memory structure proposed in these studies, it is feasible to achieve narrow DW width, high DW-position controllability, low driving current, as well as high thermal stability at the same time. Our studies provide a promising way to achieve low power consumption, high storage density, and high reliability DW motion memory easy to put into commercial production.