# Low Current Driven Vertical Domain Wall Motion Memory with Artificial Ferromagnet

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Domain wall (DW) motion in ferromagnetic nanowires is potential candidates of future memory technologies such as racetrack memory[1)]. However, there are still some problems that hampers the commercialization of DW motion memories. First, the DW width, which determined by the intrinsic properties of materials, is large (> 5 nm for Co[2)]) as far as the commercialization is concerned. Second, to precisely control DW position is a difficult task. Currently, the approach used to control DW position is to fabricate well-designed pinning sites in nanowire[1)]. This approach needs complicated nanofabrication process. Besides, lowering consumption power is also important for practical application. To attain low current driven, precisely controllable, and applicable DW motion memory with high storage density, there is still a lot of room for improvement. In this study, we propose a new type of vertical DW motion memory with artificial ferromagnet and study the feasibility with micromagnetic simulation. Based on the proposed structure, narrow DW width, DW controllability, as well as low $J_c$ down to $2 \times 10^{10}$ A/m$^2$ can be achieved.

A schematic illustration of vertical DW motion memory proposed in this study is shown in Fig. 1. A 20-nm-diameter-cylindrical magnetic wire, referred to as one memory cell, is an artificial ferromagnet. The main body of wire is composed of periodically stacked bilayers of strong coupling layers (green layers) and weak coupling layers (yellow layers). The purpose of the strong coupling layers is to carry storage bits, while the weak coupling layers carry DWs. We use micromagnetic analysis to study the feasibility of device. In this study, the magnetic exchange stiffness ($A_{ex}$) and uniaxial magnetic anisotropy constant ($K_u$) are 10 pJ/m, $10^6$ J/m$^3$, for the strong coupling layers, while 1-10 pJ/m, 0 J/m$^3$, for the weak coupling layers. We study dependences of DW width and $J_c$ on different $A_{ex}$ of weak coupling layers. The thickness of each layer is set to be 3 nm and the cell size for calculation is 1 nm cube.

Figure 2 shows the DW width as a function of $A_{ex}$ of weak coupling layers. It can be observed that, as the $A_{ex}$ decreases to smaller than 3 pJ/m, the DW width can be narrowed to only 1 layer (3 nm). In addition, if the $A_{ex}$ of weak coupling layer increased to sufficiently large, $J_c$ for DW motion can be decreased down to $2 \times 10^{10}$ A/m$^2$, as shown in Fig. 3. The results suggest that, as we optimize the $A_{ex}$ of weak coupling layers, it is possible to simultaneously achieve narrow DW and low $J_c$ in artificial ferromagnet based magnetic nanowire. This study provides a promising way to speed up the commercialization of DW motion memory.

**Reference**

1) S. Parkin, M. Hayashi, and L. Thomas, *Science*, **320**, 190 (2008).
2) L. Thomas, M. G. Samant, and S. S. P. Parkin, *Phys. Rev. Lett.*, **84**, 1816 (2000).

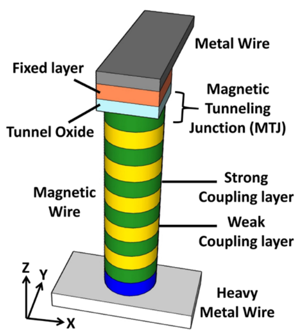


**Fig. 1.** Artificial ferromagnet based vertical DW motion memory cell proposed in this study.

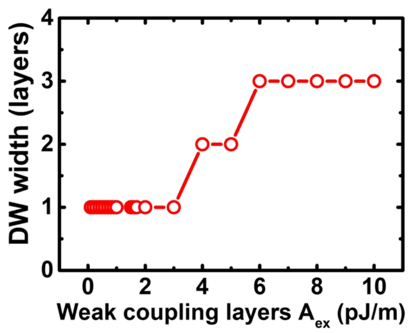


**Fig. 2.** DW width (counted with layers) as a function of weak coupling layers $A_{ex}$.

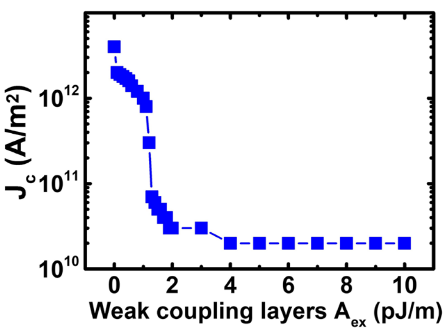


**Fig. 3.** Critical current $J_c$ for DW motion as a function of weak coupling layers $A_{ex}$.