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ナノ細線中の磁壁の熱安定性としきい電流

Thermal stability and critical current for domain wall motion in nanowire

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Spintronics-based very large-scale integrated circuits (VLSIs), where nonvolatile spintronics devices are embedded in CMOS circuits, are an effective solution to address the issues that conventional VLSI technology faces today [1]. A three-terminal device utilizing current-induced domain wall (DW) motion is a promising building block for them [2,3]. In this work, we focus on two parameters relevant to the performance of the DW-motion device: thermal stability and critical current. The former determines the retention property and the latter determines the active power and areal density. We evaluate the device size dependence of the two parameters, which is crucially important to embed into the CMOS technology.

We use Hall devices made of Co/Ni multilayers, in which an anomalous Hall effect is used for the detection of DW motion. The stack structure of the multilayer is, from the substrate side, Ta/ Pt/ $[\mathrm{Co/Ni}]_N$/ Co/ Pt/ Ta. We prepare the Hall devices with various wire widths W down to 20 nm and various stacking numbers N of the Co/Ni bilayer from 2 to 6.

We find that the critical current I_C almost linearly scales along with W whereas the thermal stability factor $E/k_\mathrm{B}T$ slightly increases as W and N decreases. As a result, the efficiency of the DW motion defined as $(E/k_\mathrm{B}T)$ / I_C [$\mu\mathrm{A}^{-1}$] increases as W and N decreases and becomes more than 2 at W = 20 nm. This indicates a promising property of the DW-motion device in terms of size reduction. It is also noteworthy that $E/k_\mathrm{B}T$ increases although the geometric volume decreases as W and N decreases. To clarify the origin, we analyze the effective volume of DW which governs $E/k_\mathrm{B}T$. We find that above a critical wire width the DW depinning is initiated with a subvolume excitation, where only a portion of DW contributes to $E/k_\mathrm{B}T$ as was seen in the magnetic tunnel junction device [4]. Also the critical width decreases as N, i.e., the thickness of magnetic layer, increases. These findings are qualitatively explained by an analytical model where Zeeman and DW elastic energies are considered.

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