Spin-wave-driven domain-wall motions in soft magnetic nanotubes

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1. 서 론

Magnetic domain-wall (DW) motions have attracted growing interest for potential future magnetic applications such as race-track memory [1] and magnetic logical devices [2]. However, a drawback of electric-currentdriven DW motions is the Joule heating [3] due to the extremely high current density. Recently, micromagnetic simulations [4] have shown that spin waves (SWs) propagating along ferromagnetic nanowires allow for DW motions without Joule heating. More recently, fundamental understanding of DW motions in three-dimensional (3D) magnetic nanotubes has been obtained from theoretical studies, numerical simulations, and several experiments. [5] As a consequence of the tubular topology and superior stability of the nanotubes, a much higher threshold field is needed to destroy the DW structures. Since fast and precisely controlled DW motion is a prerequisite for operations performed by such devices, herein we present the results of a study on the interaction of SWs and DWs in nanotubes.

2. 실험방법과 결과

We here report a micromagnetic simulation study on interactions between propagating SWs and a vortex DW in cylindrical magnetic nanotubes[6]. In such cylindrical nanotubes, we found that DW propagation speed is sensitive to both SW amplitude and its frequency. From a fast Fourier transformation analysis of SWs, we found that DW speed is quantitatively correlated with SW amplitude change. We also determined that the DW moves away from the SW source over a wide frequency range, ata velocity that is an order of magnitude faster than in flat nanostrips. Partial or complete reflection of spin wave salso occurs at complex vortex DWs in cylindrical nanotubes, in which momentum transfers between the SW and DWs give rise to specific torques acting on the DW that allow for DW movement in the same direction as that of the incident SWs. Overall, this work provides a fundamental understanding of SW and DW interactions in magnetic nanotubes and shows the way to potential applications in future all-magnonic spin-wave devices.

3. 고 찰

The transmittance in the f_0 = 13 – 18 GHz range is extremely small, as low as ~ 10^{-4}. This almost zero transmittance of SWs across the DW represents almost complete reflection of incident SWs from the DW placed in the SW guide. This observation is consistent with the fact that propagating SWs can be totally reflected from a DW in cases where SW’s wavelengths are larger than the width of a DW. Thereby, the magnonic linear momentum is transferred completely to the DW, so that the DW can move forward at a remarkably high speed on the order of a few hundreds of m/s or higher. Such strong SW reflection from DWs is a unique behavior in the nanotube geometry, because the lack of a lateral boundary makes the DW stable, subsequently yielding a stronger interaction with incident SWs. Accordingly, the strong SW reflection by the stray fields arising from the vortex-type DW can impart magnonic linear momentum transfer torques to the DW. Moreover, the internal normal oscillation modes of the DW also influence DW motions, resulting in an additional reflection of incident SWs. As reported earlier, magnonic linear momentum transfer torques from SWs' reflection is an order of magnitude more effective than spin angular momentum transfer torques arising from. Such reflection of SWs from a DW plays a key role in magnonic linear momentum transfer to the DW. Our simulation results and interpretations unambiguously reveal that the DW speed is enhanced just by manipulating the frequency and amplitude of SWs excited in nanotube geometries.

4. 결 론

In summary, we studied the interaction between propagating SWs and a vortex-like DW in a specific nanotube geometry, and found SW-driven, fast DW motions. The DW speed is determined by the SW amplitude and frequency in a nanotube of given dimensions, and was as high as ~660 m/s in this study. Based on the data of the amplitude and transmission coefficient of SWs passing across the DW, we found that magnonic linear momentum transfer torques, arising from the strong reflection of SWs from the DW in a specific nanotube geometry, allow for fast DW motion in the same direction as that of the incident SWs of a specific frequency band, here f_0 = 13 – 18 GHz. This work constitutes an important step toward the achievement of all-magnetic-based DW memory and logic devices based on fast DW motion.

5. 참고문헌

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