Magnetization dynamics and domain wall motion induced by circular rotating magnetic fields in soft magnetic nanotubes

Jaehak Yang[1*], Junhoe Kim[1], Bosung Kim[1], Young-Jun Cho[1], Jae-Hyeok Lee[1] and Sang-Koog Kim[1]

[1]National Creative Research Initiative Center for Spin Dynamics and Spin-Wave Devices, Nanospinics Laboratory, Research Institute of Advanced Materials, Department of Materials Science and Engineering, Seoul National University, Seoul 151-744, South Korea

1. Introduction

Magnetic domain-wall (DW) motions in thin-film rectangular-shape nanostripes have attracted significant attentions because of their technological applications in magnetic memory [1] and logic devices [2]. However, one of the main challenges is the suppression of the DW mobility due to the Walker breakdown behavior, in which DWs are periodically transformed from the transverse to vortex walls [3]. Further theoretical works found that the Walker breakdown behaviors can be hindered and/or reduced using specific geometrical confinements of cylindrical nanowires [4] and nanotubes [5]. They have curved geometries that differ from flat thin films and thereby leading to the geometrical confinement of local magnetizations in such structures. Locally different demagnetization fields can thus influence the dynamics of local magnetizations and their collective intrinsic modes. Since systematic study of spin-wave modes as related to the DW motions is a prerequisite for operations performed by such devices, herein we present the results of a study on the magnetization dynamics as well as DW motions in a cylindrical nanotube.

2. Method & Results

We studied, by micromagnetic numerical calculations [6], magnetization dynamics as well as DW motions in a cylindrical nanotube with a head-to-head DW, driven by circular rotating fields of different frequencies. We found the presence of two different localized DW oscillations, ferromagnetic resonance, and azimuthal spin-waves modes at the corresponding resonant frequencies of circular rotating magnetic fields. Associated with these intrinsic modes, there exist very contrasting DW motions of different speeds and propagation directions for a given DW chirality. The direction and speed of the DW propagation were found to be controllable with the rotation sense and the frequency of circular rotating magnetic fields. Furthermore, spin-wave emissions from the moving DW were observed at a specific field frequency along with their *Doppler effect*.

3. Discussions

From an application point of view, such magnetic nanotubes studied here can be used as a DW racetrack and have several advantages such as a high stability of DWs and hindering the Walker breakdown due to the geometrical confinements of local magnetizations. Also, the DW chirality provides a further degree of freedom, which can be detected via the direction of DW propagations for a given rotation sense of the circular rotating fields. Furthermore, the stray fields of the DWs play a crucial role in trapping magnetic particles inside a nanotube, which may provide an on-chip system for capturing, manipulation, and delivery of individual magnetic nanoparticles in bio-applications, as well as information storage and processing devices.

4. Conclusion

We report on intrinsic spin-wave excitations and these related very contrasting DW motions in soft magnetic nanotubes of a vortex-type DW. We found that the speed and direction of DWs in the nanotube are reliably controllable with the rotation sense and frequency of circular rotating magnetic fields for a given DW chirality. This work provides fundamental correlations between the characteristic DW motions and excited spin-wave modes and furthermore constitutes an important step toward the achievement of all-magnetic-controlled DW motions, applicable to magnetic memory and logic devices using DW motions.

5. References

[1] S. S. P. Parkin, M. Hayashi, and L. Thomas, “Magnetic Domain-Wall Racetrack Memory”, Science **320**, 190 (2008).

[2] D. A. Allwood, G. Xiong, C. C. Faulkner, D. Atkinson, D.Petit, and R. P. Cowburn, “Magnetic domain-wall logic”, Science **309**, 1688 (2005).

[3] J.-Y. Lee, K.-S. Lee, S. Choi, K. Y. Guslienko, and S.-K. Kim, “Dynamic transformations of the internal structure of a moving domain wall in magnetic nanostripes”, Phys. Rev. B **76**, 184408 (2007).

[4] M. Yan, A. Ka´kay, S. Gliga, and R. Hertel, “Beating the Walker Limit with Massless Domain Walls in Cylindrical Nanowires”, Phys. Rev. Lett. **104**, 057201 (2010)

[5] M. Yan, C. Andreas, A. Ka´kay, F. Garcı´a-Sa´nchez, and R. Hertel, “Fast domain wall dynamics in magnetic nanotubes: Suppression of Walker breakdown and Cherenkov-like spin wave emission”, Appl. Phys. Lett. **99**, 122505 (2011)

[6] D. Suess, and T. Schrefl, FEMME: Finite Element MicroMagnEtics 5.0.9 (SuessCo, http://suessco.com/).