T07

Physical Origin and Generic Control of Magnonic Band Gaps of Dipole-Exchange Spin Waves in Width-Modulated-Nanostrip Waveguides

Ki-Suk Lee*, Dong-Soo Han and Sang-Koog Kim
Research Center for Spin Dynamics and Spin-Wave Devices, Seoul National University and
Nanospinics Laboratory, Department of Materials Science and Engineering, College of Engineering, Seoul National University, Seoul 151-744, Republic of Korea

1. Introduction

Recently, it has been recognized that the spin waves (SWs) as an information carrier is a promising technique to provide solution to the limitation of the semiconductor electronics because the SW based signal processing devices can transmit information without an electron transport [1]. The periodic structure of magnetic materials, the magnonic crystal (MC), has been attracting much attention, owing to its applications to spin-wave (SW) filters [2] and spin-wave logic devices [3]. In recent years, many theoretical and experimental studies have been performed on various types of MCs including one-dimensional structures [4] such as periodic multilayers, corrugated films as well as 2D or 3D structures [5]. In MC structures, the allowed and forbidden SW modes (called magnons) are controllable by a variety of artificial periodic structures of magnetic media with different magnetic properties, for example, magnetic and geometric parameters. Despite these recent theoretical and experimental studies, there are fewer studies on simple planar structures of MC waveguides for practical applications [6]. In this presentation, we propose a new type of MC waveguides of a simple-planar-patterned thin-film nanostrip in which magnonic bands and band gaps can be manipulated by means of the periodic modulation of different strip widths [7].

2. Simulations

In order to understand the physical origins of the allowed and forbidden bands in proposed nanostrip MCs and to elucidate their relations to geometrical width modulation, we performed micromagnetic simulations and analytical calculations of SW propagations in nanostrip MCs. As a model, we used 10 nm thick Py nanostrips of different width (24 and 30 nm) modulations with periodicity P ranging from 12 to 42 nm. For micromagnetic simulations, we used the OOMMF code (version 1.2a4) [8] to calculate the values numerically by applying them to the Landau-Liftshitz-Gilbert equation and the Runge-Kutta method. We used the standard material parameters of Py: the saturation magnetization Ms = 8.6 × 105 A/m, the exchange stiffness Aex = 1.3 × 10-11 J/m, the Gilbert damping constant α = 0.01, and the unit cells of 1.5 × 1.5 × 10 nm3. To excite the lowest mode dipole-exchange spin waves (DESWs) for a given nanostrip, with the frequencies ranging from 0 to 100 GHz, we applied an external magnetic field with a "sine cardinal (sinc)" function form having 1T peak field strength, only on the local area (the left edge of the nanostrip). By this localized field excitation, the lowest mode DESWs are excited at the left edge of the Py nanostrip and subsequently propagated along the direction of the length.

3. Results and Discussion

From the frequency spectra obtained from the fast Fourier transform (FFT) of the temporal Mz/Ms evolution for

DESW propagations along the length direction of the nanostrip MCs, we found that a new type of MCs of the periodic modulation of different strip widths yields complex DESW band structures and wide band gaps (~10GHz). From the comparisons of the dispersion relations obtained from micromagnetic simulations with the analytical calculations, we found that the complex DESW band structures and wide band gaps originate from the diagonal coupling between the identical lowest modes. and also between the initially propagating lowest mode and the higher-quantized width mode newly excited through the DESWs scattering at the periodic edge steps of different-width-modulated nanostrips. Furthermore, we discovered that the width, the position, and the number of the magnonic band gaps are controllable by the periodicity and the motif of the periodic strip-width modulation. From an application perspective, this novel property of width modulated nanostrip MCs can be implemented as an effective means of manipulating the allowed DESW modes in their propagations through such width-modulated nanostrips.

4. Conclusions

We found that complex DESW band structures and wide band gaps originate from the diagonal or off-diagonal coupling between the initially propagating lowest DESW mode and the identical or higher-quantized width mode newly excited through the DESWs scattering at the edge steps of different-width-modulated nanostrips. These findings can offer a shortcut to the potential application to broadband spin wave filters in the GHz frequency range. This work was supported by Creative Research Initiatives (Research Center for Spin Dynamics & Spin-Wave Devices) of MEST/KOSEF.

5. References

[1] S. Choi et al., Phys. Rev. Lett. **98**, 087205 (2007); A. Khitun et al., Nanotechnology 18, 465202 (2007).

[2] R. L. Carter et al., J. Appl. Phys. **53**, 2655 (1982).

[3] R. Hertel, W. Wulfhekel, and J. Kirschner, Phys. Rev. Lett. **93**, 257202 (2004); T.Schneider et al., Appl. Phys. Lett. **92**, 022505 (2008); K.-S. Lee and S.-K. Kim, J. Appl. Phys. **104**, 053909 (2008).

[4] M. P. Kostylev et al., Appl. Phys. Lett. **87**, 153501 (2005); Schneider et al., Appl. Phys. Lett. 92, 022505 (2008).

[5] J. O. Vasseur, L. Dobrzynski, and B. Djafari-Rouhani, Phys. Rev. B **54**, 1043 (1996); M. Krawczyk and H. Puszkarski, Phys. Rev. B **77**, 054437 (2008).

[6] A. V. Chumak et al., Appl. Phys. Lett. **93**, 022508 (2008).

[7] K.-S. Lee, D.-S. Han, and S.-K. Kim, Phys. Rev. Lett. **102**, 127202 (2009).

[8] See http://math.nist.gov/oommf