# Spin Dynamics in CoFeB Nanowires using Micro-fabricated Coplanar Wave Guide

Jaehun Cho[1]*, Jungbum Yoon[1], Fujii Yuya[2], Konishi Katsunori[2], Suzuki Yoshishige[2] and Chun-Yeol You[1]
[1]Department of Physics, Inha University
[2]Division of Materials Physics, Graduate School of Engineering Science, Osaka University

## 1. Introduction

Ferromagnetic nanostructures have recently attracted much interest for the wide potential applications in data storage, magnetic sensors and microwave devices [1]. In long wires with a small diameter, the shape anisotropy may allow ferromagnetic nanowire devices to be operated without an external magnetic field [2]. However, more studies are needed to understand the spin dynamics properties in the nanowires with the shape anisotropy energies. In this study, we experimentally investigate the ferromagnetic resonance of the nanowires. We also calculate the ferromagnetic resonance using micromagnetic simulations with the same figures in the experimentally studied nanowires.

## 2. Experiment and Micromagnetic simulations

We measured the ferromagnetic resonance of the ferromagnetic nanowires. Electrically shorted coplanar waveguides were fabricated on 30-nm-thick $Co_{16}Fe_{64}B_{20}$ film with a lateral size of 5 x 250 x $\mu m^2$ (rectangular), and array of nanowires of 100 nm x 250 μm (longitudinal) and 100 nm x 5 μm (transverse) with a gap of 200 nm between nanowires using liftoff technique. The magnetic properties of nanowires are examined with the vector network analyzed ferromagnetic resonance measurement. For maicromagnetic simulations, the object oriented micromagnetic framework (OOMMF) code is used to solve the Landau-Lifshitz-Gilbert (LLG) equation [3].

## 3. Results

The frequencies of the spinwaves versus the applied magnetic field are plotted in Fig. 1. The frequencies of each modes are analyzed using Kittel's equation [4]

$$f = \frac{\gamma}{2\pi}\left(\left[H + (N_y - N_z)M\right]\left[H + (N_x - N_z)M\right]\right)$$

$H$ is the applied magnetic field, $\gamma$ is the gyromagnetic ratio, $N_x, N_y, N_z$ are the demagnetization factors, $M_s$ is the saturation magnetization. The saturated magnetization was determined by thin film, and the demagnetization factors was determined by the longitudinal and transverse patterns. Changing thin film to longitudinal (transverse) patterns, resonance frequencies increase (decrease). It may cause by the shape anisotropy of longitudinal (transverse) patterns. From the standard fitting procedures, we find taht the saturated magnetization and demagnetization factors (*Nx, Ny, Nz*) in longitudinal wire are 1.579 × $10^6$ A/m and (0.008, 0.125, 0.867) respectively.

We considered periodic boundary condition (PBC) in the micromagnetic simulations for infinite nanowires. Figure 1 shows the figure of PBC nanowire with 100-nm-long, 100-nm-wide, and 10-nm-thick CoFeB. Each nanowire is separated 200 nm in y-axis, the cell size is 5 × 5 × 5 $nm^3$. The material parameters of CoFeB are used in our simulation are summarized as follows: the saturation magnetization 1.579 × $10^6$ A/m, the exchange stiffness 1.5 × $10^{-11}$ J/m, the gyromagnetic ratio 2.32 × $10^5$ m/(A·s) and we ignore the magneto-crystalline anisotropy. In this simulation, the Gilbert damping parameter of 0.01 is fixed.

## 4. Summery

In summary, the ferromagnetic resonance experiments was applied to investigate the magnetic properties of $Co_{16}Fe_{64}B_{20}$ thin films and nanowire patterns. We find that the saturated magnetization and demagnetization factors. And we will compare experimental result with the micromagnetic simulations.

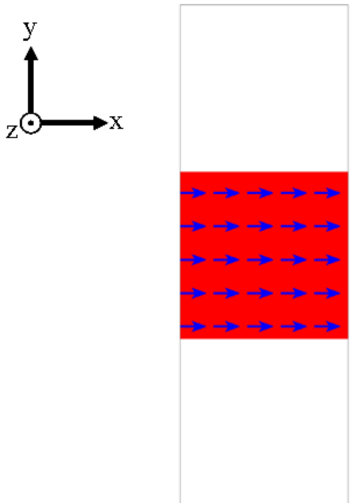


**Fig. 1** Magnetization configuration of the CoFeB nanowire with Periodic Boundary Condition.

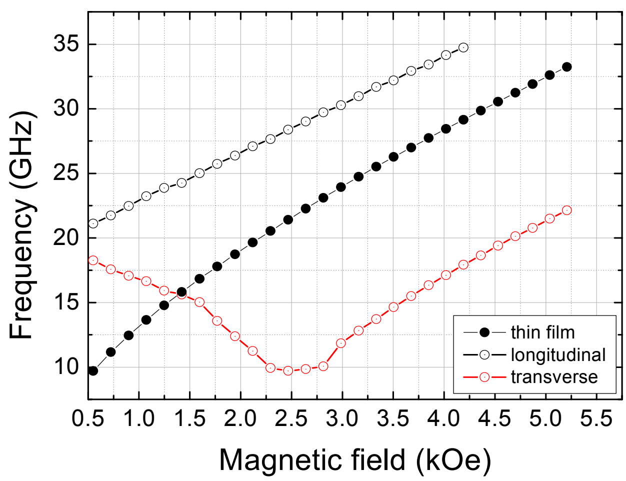


**Fig. 2** Variation of spin wave frequency with an applied field. The black closed circles are thin film, black open circles are longitudinal patterns, and red open circles are transverse patterns.

## 5. Reference


[1] Tao Li *et al*, J. Physics.: Condens. Matter., **17**, 3637(2005).

[2] Louis-Philippe Carignan *et al.* Appl. Phys. Lett., **95**, 062504(2009).

[3] See </http://math.nist.gov/oommf>.

[4] C. Kittel, Introduction to Solid State Physics, 7th edition, John Wiley & sons, 1996, p. 505.