Micromagnetic simulation of magnetic nano-particles detected using spin-wave

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Spin-wave is a collective excitation of magnetization precession, derived from the Landau-Lifshitz-Gilbert (LLG) equation [1], and those wave properties are varied with an external and effective magnetic field. Recently, a magnetic field sensing using spin-wave has been proposed, and a highly sensitive sensor has been demonstrated [2]. Our idea is to extend this spin-wave sensing for virus detection utilizing magnetic nano-particles for potential medical applications. To clarify this feasibility, we investigate an effect of presence of a magnetic nano-particle on spin-wave propagation using numerical simulations.

Figure 1 shows a schematic diagram of structure used in the simulation. Numerical simulation was performed using Mumax[3] [4]. We assumed a magnetic nano-particle as a nano-pillar with diameter varied, for simplicity. Rf magnetic field was locally applied to a left-end of a spin-wave channel for an excitation, and a propagating spin-wave was detected at the right-end. The x component of magnetization vector $\boldsymbol{M}$ at the right-end was evaluated using a Fast Fourier Transform (FFT) to characterize a transmittance and so on. Figure 2 shows the spin-wave transmittance as a function of the diameter of magnetic nano-pillar, which was evaluated at the rf excitation frequency f of 9 GHz. The spin-wave transmittance T_r is defined as $m_x(f) / m_{x0}(f)$ obtained from FFT. Here, $m_x(f)$ and $m_{x0}(f)$ are the transmission amplitude of spin-wave in the frequency domain with and without a nano-pillar, respectively. As shown in the figure, the spin-wave transmittance is significantly reduced when the magnetic nano-pillar is present. We can still observe a finite reduction of the transmittance even at those diameters of less than 100 nm, indicating feasibility of magnetic nano-particle detected using spin-wave. We will discuss these results and issues to be addressed in the presentation.

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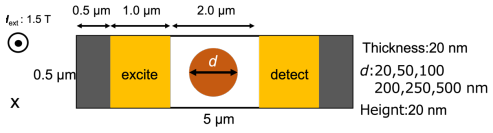

Fig. 1 Schematic diagram of the simulation.

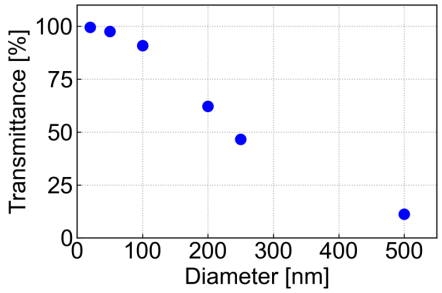

Fig. 2 Magnetic nano-pillar diameter dependence of the transmittance T_r of spin-wave at the detection position.