THEORETICAL STUDY OF SPIN WAVE-ASSISTED SWITCHING OF MAGNETIZATION IN A PERPENDICULARLY MAGNETIZED NANOMAGNET

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I. INTRODUCTION

Microwave assisted switching (MAS) of magnetization has attracted much attention as a novel switching technique to reduce the switching field of ultra-high-density magnetic recording media [1]. The reduction of the switching field of MAS of a nanomagnet is well understood by analyzing the dynamics based on the macrospin-model in a rotating frame synchronized with a radio frequency (rf) field. In the rotating frame, the rf field acts as a static field parallel to the rotating axis and reduces the switching field. For MAS, however, a certain critical frequency, f_c, exits. A switching field, H_{SW} monotonically decreases with the increase in rf frequency, f, and it takes a minimum value H_{min} at f_c. Once f exceeds f_c, the H_{SW} shows a sudden increase and reaches almost the same value as that without the rf field. Thus in principle, H_{min} is the limiting value to which H_{SW} can be reduced in MAS.

Recently, a more effective reduction of the switching field than the conventional MAS technique has been reported using a spin wave excitation in nanomagnet systems [2,3]. For example, in the case of FePt/permalloy bilayers [2], the switching field of FePt was significantly reduced by the assistance of the spin wave excited in permalloy layer. In addition, in a single Co/Pt nanodot [3], f_c increased due to the spatially non-uniform magnetization precession, i.e., the spin wave was excited in the circular magnetic dot, and the switching field decreased more than the conventional MAS. Although experimental studies such as above have been reported so far indicating the reduction of the switching field due to a spin wave excitation, the mechanism of the so-called “spin wave-assisted switching” dynamics still remains unclear.

We studied the MAS of a perpendicularly magnetized nanomagnet by numerically solving the Landau-Lifshitz-Gilbert (LLG) equation for the effective one-dimensional spin model where each perpendicularly magnetized cell with 1nm thickness is coupled to another by exchange stiffness coupling, A_{ex}, shown in Fig. 1(a). By investigating the thickness dependence of the switching field, two kinds of critical thicknesses were found for the types magnetization dynamics and for the rf frequency dependence of the switching field [4].

II. RESULTS AND DISCUSSION

Figure 1(b) shows the switching field as a function of the frequency of the rf field, f, for d = 20 nm as the typical case of the small thickness, and for d = 100 nm, as that of the large one. The switching field is calculated by numerically solving the LLG equation. Similar to MAS for the uniform mode magnetization dynamics, H_{sw} monotonically decreases with the increase in f and takes a minimum value at a certain critical frequency, f_c. Once f exceeds f_c, H_{sw} shows a sudden increase and reaches almost the same value as that without the rf field. When d = 20 nm, f_c is the same as the result which is calculated by the single macro-spin model, whereas in the case of d = 100 nm, f_c increases, and the switching field is further reduced compared with that obtained for d = 20 nm.

Let us discuss the thickness dependence of the switching dynamics and the switching field in detail. Here, the spin wave amplitude, A_{sw}, is introduced. The spin wave mode excited in this one-dimensional spin model is a perpendicular standing spin wave (PSSW) mode. Figure 2(a) shows the schematic illustration of the PSSW mode excited in this model and the definition of A_{sw}. In this study, therefore, A_{sw} is defined as the difference between the maximum value and the minimum one of the in-plane component. The thickness dependence of A_{sw} at f_c, and also the thickness dependences of f_c and H_{min} are shown in Figs. 2(b) and 2(c), respectively. As seen in

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Fig. 2(b), A_{sw} suddenly increases above the thickness, 52nm. This thickness is regarded as the first critical thickness, d_{c1}. The dispersion on the thickness dependence of A_{sw} might be due to the quasi-periodic magnetization mode, which appears around f_{c}. On the other hand, Fig. 2(c) shows that f_{c} increases above the thickness, 82nm, resulting in the decrease in H_{min}. This thickness at which f_{c} starts to increase can be regarded as the second critical thickness, d_{c2}. It suggests that in the region $d_{\mathrm{c1}} \leqq d < d_{\mathrm{c2}}$, A_{sw} is not large enough to increase f_{c}.

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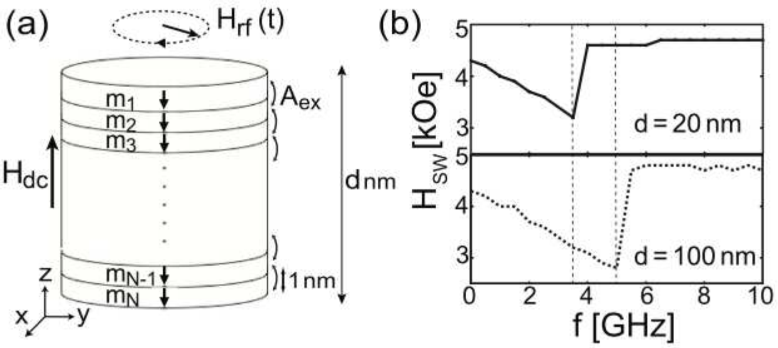

Fig. 1 (a) A schematic illustration of an effective one-dimensional spin model of a perpendicularly magnetized nanomagnet. (b) The switching field as a function of *f*.

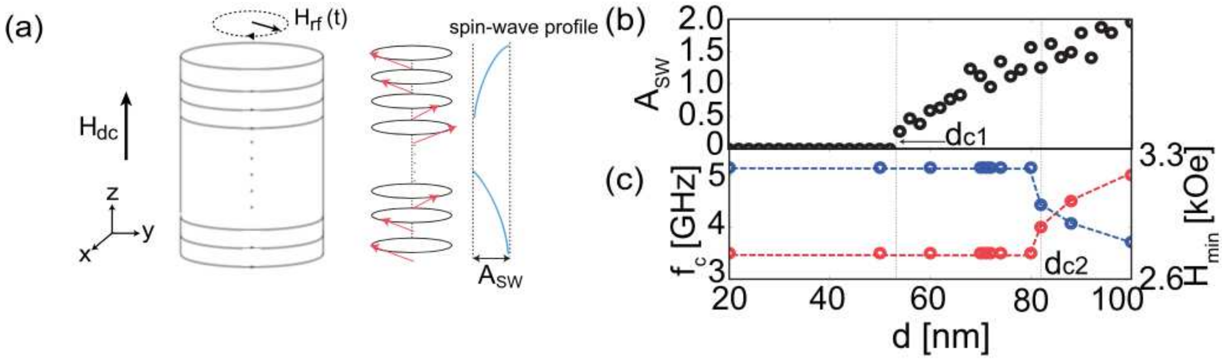

Fig. 2 (a) The schematic illustration of the PSSW mode excited in this one-dimensional spin model and the definition of A_{sw}. (b) The thickness dependence of A_{SW} at f_{c}. (c) The thickness dependences of f_{c} and H_{min}. f_{c} and H_{min} are plotted by the red and blue circles, respectively.