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Spin Wave-Assisted Magnetization Switching in Nanometer-Scaled Bilayer Elements

Takeshi Seki[1], Weinan Zhou[1] and Koki Takanashi[1]

[1]Institute for Materials Research, Tohoku University,
2-1-1 Katahira, Aob-ku, Sendai 980-8577, Japan
Phone: +81-22-215-2097 E-mail: go-sai@imr.tohoku.ac.jp

Abstract

Magnetization switching assisted by the spin wave excitation is a promising technique to reduce the power consumption in magnetic storage and spintronic devices. Previously, we demonstrated the switching field reduction utilizing the spin wave modes in the μm-scaled $L1_0$-FePt / Permalloy bilayer elements. In this study, we investigated spin wave-assisted magnetization switching in nm-scaled elements, and observed the switching field reduction as well as the μm-scaled ones.

1. Introduction

Highly efficient magnetization switching needs to be developed for high performance magnetic storage and spintronic devices in order to reduce the power consumption of the operation. Recently, we have experimentally demonstrated a new switching technique: spin wave-assisted magnetization switching [1, 2]. This technique utilized the characteristic spin wave modes in $L1_0$-FePt / Permalloy (Py) bilayers, in which the $L1_0$-FePt and Py layers were exchange-coupled through the interface. We obtained the large reduction in switching field (H_{sw}) by spin wave excitation. Although the previous results suggest the applicability of spin wave-assisted magnetization switching to an information writing method of magnetic storage device, the experiments were carried out using the μm-scaled elements, which is not suitable for actual device applications. Thus, we need to examine the magnetization switching characteristics in a nm-scaled element.

In this study, we investigated spin wave-assisted magnetization switching in nm-scaled $L1_0$-FePt / Py bilayer elements. The arrays of rectangular elements were microfabricated through the use of a lithographical technique. In order to evaluate the magnetization switching of the element arrays, we measured the anisotropic magnetoresistance (AMR) curves under the application of a pulsed rf magnetic field (H_{rf}). We successfully observed the switching field reduction as well as the μm-scaled ones by using the pulsed H_{rf} measurement.

2. Sample Preparation

Thin films were prepared on an MgO (110) substrate employing a sputtering method. The stacking structure of the film is / Fe (2) / Au (40) / $L1_0$-FePt (7) / Py (120) / Au (3) (in nanometers). The $L1_0$-FePt layer was deposited at 525ºC to promote the $L1_0$ ordering, which led to the in-plane uniaxial magnetic anisotropy. On the other hand, the Py layer was deposited at room temperature, showing soft magnetic behavior. The $L1_0$-FePt / Py bilayer formed twisted magnetic structures by applying in-plane magnetic field [3].

The $L1_0$-FePt / Py bilayers were patterned into rectangular elements. Figure 1 shows a scanning microscope image of the array of rectangular elements prepared on the signal line of coplanar waveguide. The width and the length of rectangular element were 200 nm and 1 μm, respectively, which are much smaller than the previous bilayer element with the size of 2 x 50 μm [1, 2]. The longitudinal axis of rectangle corresponds to the easy magnetization axis of in-plane magnetized $L1_0$-FePt layer.

3. Measurement Sequence

H_{sw} was evaluated by measuring the minor AMR curves. The measurement sequence using the pulsed H_{rf} is as follows. Without applying H_{rf}, the static magnetic field (H) was swept from the positive field to negative one, which led to the change in the magnetic structure from the saturated state to the twisted one. At a certain H, where the twisted magnetic structure was formed, pulsed H_{rf} was applied to the device. After the application of pulsed H_{rf}, H was swept back to the positive field. When the magnetization switching was triggered by the H_{rf} application, the resistance change was observed by sweeping H from negative to positive owing to the formation of twisted magnetic structure. The pulsed H_{rf} was applied using a

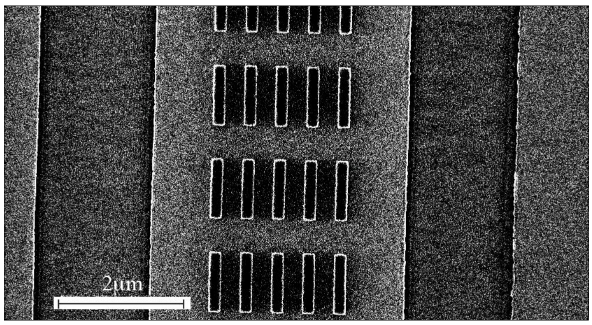

Fig. 1 Scanning microscope image of the array of $L1_0$-FePt / Permalloy rectangular elements. The array was prepared on the signal line of coplanar waveguide. The width and the length of rectangular element were 200 nm and 1 μm, respectively.

structure. The pulsed H_{rf} was applied using a signal generator, and its duration time was set to 200 msec. All the measurement was carried out at room temperature.

4. Results and Discussion

The AMR curves for the array of $L1_0$-FePt / Py bilayer elements are shown in Fig. 2. The open circles denote the full AMR curve whereas the solid circles denote the minor AMR curves. Figures 2a and 2b show the results for H_{rf} of 134 Oe with the frequencies (f) of 4 GHz and 12 GHz, respectively. The pulsed H_{rf} was applied at H = -1500 Oe. In the case of f = 4 GHz, no abrupt resistance increase was observed even after applying the pulsed H_{rf}. Thus, a resistance decrease did not appear in the positive H region when H was swept from negative to positive. This means that the application of pulsed H_{rf} did not lead to magnetization switching in the case of f = 4 GHz. On the other hand, the resistance increase and decrease were observed in the negative and positive H regions, respectively, when the pulsed H_{rf} of f = 12 GHz was applied at H = -1500 Oe. The minor AMR curve after the pulsed H_{rf} application was not equal to the full AMR curve, indicating that the magnetization

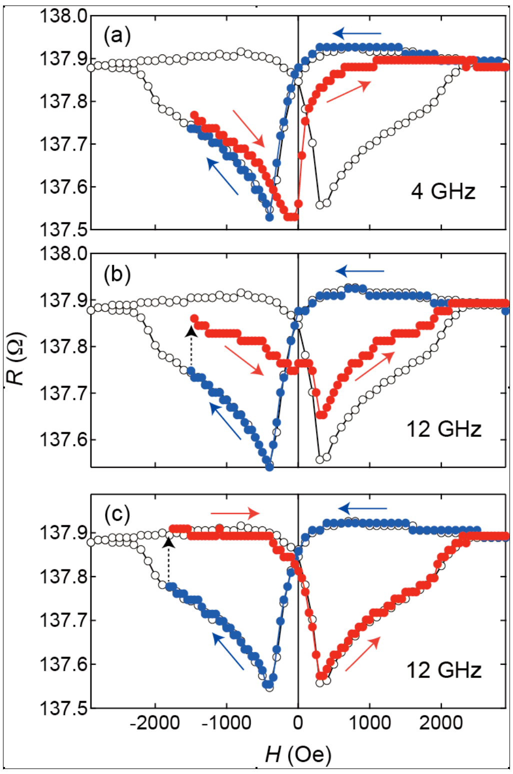

Fig. 2 Anisotropic magnetoresistance (AMR) curves for the array of $L1_0$-FePt / Py rectangular elements. The open circles denote the full AMR curve whereas the solid circles denote the minor AMR curves. (a) Pulsed rf magnetic fields (H_{rf}) of 134 Oe with the frequencies of 4 GHz and (b) 12 GHz, which were applied at H = -1500 Oe. (c) H_{rf} of 12 GHz applied at H = -1800 Oe.

switching occurred in a part of elements when the pulsed H_{rf} was applied. The ferromagnetic resonance measurement suggested that f = 12 GHz was close to a spin wave resonance frequency at H = -1500 Oe. Thus, the partial magnetization switching implies the switching field distribution of spin wave-assisted magnetization switching in the element array. When H was set to -1800 Oe (Fig. 2c), all the elements showed magnetization switching after the application of H_{rf} of f = 12 GHz. Consequently, the switching field was successfully reduced for the nm-scaled elements as well as the μm-scaled.

5. Summary

We investigated spin wave-assisted magnetization switching in nm-scaled $L1_0$-FePt / Py bilayer elements. The switching field reduction was observed by exciting the spin wave mode. In addition, the partial magnetization switching implied that there existed the switching field distribution of spin wave-assisted magnetization switching in the element array.

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