Time-Domain Analysis of Magnetization Reversal Process with Microwave Assist

Shinichiro Ohnuki\textsuperscript{1}, Akira Kuma\textsuperscript{1}, Yuta Takano\textsuperscript{1}, Arata Tsukamoto\textsuperscript{1}

\textsuperscript{1}Department of Electrical Engineering, College of Science and Technology, Nihon University
1-8-14 Surugadai, Kanda, Chiyoda-ku, Tokyo, 101-8308, Japan

Abstract – For higher density magnetic recording, MAMR (Microwave Assisted Magnetic Recording) with bit patterned media has attracted attention. In this paper, we investigate magnetization reversal processes in bit patterned recording media without/with microwave assist by using multiphysics simulation.

Index Terms — MAMR, Multiphysics Simulation, Micromagnetics, Electromagnetics

I. INTRODUCTION

To realize higher density magnetic recording, MAMR (Microwave Assisted Magnetic Recording) with bit patterned recording media has attracted attention\cite{1},\cite{2}. Using this method, recording density can be achieved over 2 Tbits/inch\textsuperscript{2}.

In this paper, we investigate magnetization reversal in bit patterned recording media with microwave assist. We will perform time-domain multiphysics simulation which consists of electromagnetic simulation based on the Maxwell’s equation and micromagnetic simulation based on the Landau-Lifshitz-Gilbert (LLG) equation. Characteristics of magnetization reversal processes without/with microwave assist will be clarified.

II. COMPUTATIONAL MODEL AND METHOD

Fig. 1 shows the computational model of bit patterned recording media and their magnetization: all the magnetization vectors point to the positive z direction. To assist the magnetization reversal, the incident electromagnetic wave impinges on the target medium which is located at the center.

Magnetization in bit patterned recording media is calculated by micromagnetic simulation based on the following LLG equation:

\[
\frac{d\mathbf{M}}{dt} = -\gamma \mathbf{M} \times \mathbf{H}_{\text{eff}} + \frac{\alpha}{M_s} \mathbf{M} \times \frac{d\mathbf{M}}{dt},
\]

where

\[
C_1 = -\Delta t \frac{\gamma}{1 + \alpha^2}, \quad C_2 = -\Delta t \frac{\gamma \alpha}{(1 + \alpha^2)M_s}.
\]

In (3), \(\mathbf{M}\) is the magnetization vector, \(M_s\) is the saturation magnetization, \(\gamma\) is the gyromagnetic ratio, and \(\alpha\) is the damping constant. \(\mathbf{H}_{\text{eff}}\) is the effective magnetic field which consists of the AC field \(\mathbf{H}_{\text{AC}}\) given by the incident wave, the external reverse field \(\mathbf{H}_{\text{DC}}\), the anisotropy field \(\mathbf{H}_k = H_k(m_z/M_s) \mathbf{\hat{z}}\), with the z component of the magnetization vector \(m_z\), and the magnetostatics field \(\mathbf{H}_k\). Here the AC field is computed by the FDTD method.

We apply the finite-difference time-domain (FDTD) method to Maxwell’s equations to compute the incident microwave and electromagnetic fields in bit patterned media.

\[
\nabla \times \mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t},
\]

\[
\nabla \times \mathbf{H} = \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \mathbf{J}.
\]

The finite difference equation for the electromagnetic fields are expressed by,

\[
\mathbf{H}^{n+1/2} = \mathbf{H}^{n-1/2} - \frac{\Delta t}{\mu_0} \nabla \times \mathbf{E}^n,
\]
\[ E^{n+1} = E^n - \frac{\Delta t}{\varepsilon_0} \nabla \cdot \left( \nabla H \right)^{n+1/2} \tag{7} \]

Time-domain multiphysics simulation can be achieved by using (2), (6), and (7).

III. NUMERICAL RESULTS

We investigate magnetization reversal without/with microwave assist. The AC field \( H_{AC}/H_k \) is applied from 0.00 nsec, where \( H_k = 4.6 \times 10^5 \text{ A/m} \) and the frequency is 9 GHz. The external reverse field is applied at 1.0 nsec.

Fig. 2 shows the time response of magnetic fields and magnetization when \( H_{DC}/H_k = 0.85 \) without the AC field, that is \( H_{AC}/H_k = 0.00 \). The normalized DC and AC fields are presented in Fig.2 (a). The field distribution of the normalized magnetization \( m_z/M_s \) at 0.00 nsec, 1.50 nsec, and 3.00 nsec are presented in Fig.2 (b). Magnetization of the target medium is reversed from \(+z\) to \(-z\) direction at 3.00 nsec, however, reversal also occurs in all the neighboring media.

Fig. 3 shows the result when \( H_{DC}/H_k = 0.45 \) with microwave assist, that is \( H_{AC}/H_k = 0.15 \). We assume that the target medium is only exposed to the incident electromagnetic wave. Magnetization of the target medium is only reversed with about 50\% of the DC field compared to the case without microwave assist.

IV. CONCLUSION

We studied magnetization reversal of microwave assisted magnetic recording in the bit patterned media. For the case with microwave assist, magnetization of the target medium is only reversed and the required DC field can be reduced by about 50\%.

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REFERENCES


