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Accumulative Magnetic Switching of Ultrahigh-Density Recording Media by Circularly Polarized Light

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Abstract

Magnetization control of ferromagnetic materials only by circularly polarized light has received increasing attention both as a fundamental probe of the interactions of light and magnetism but also for future highdensity magnetic recording technologies. Here we show that for granular FePt films designed for ultrahighdensity magnetic recording, the optical magnetic switching by circularly polarized light is an accumulative effect from multiple optical pulses. The measured results can be reproduced by a simple statistical model where the probability of switching a grain depends on the helicity of the optical pulses. We further show the deterministic switching of high-anisotropy materials by the combination of circularly polarized light and modest external magnetic fields, thus, revealing a pathway towards technological implementation.

1. Introduction

Deterministic control of magnetization by light, often referred to as all-optical switching (AOS), is an attractive recording method because magnetization control becomes possible without the need of an external magnetic field [1-5]. The first experimental demonstration of the magnetization switching by light was in ferrimangnetic GdFeCo film which is a magneto-optical material1 where the Gd and FeCo spin sub-lattices are antiferromagnetically exchange coupled.

Since the mechanism determined for GdFeCo films required antiparallel exchange of two sublattice systems, it was believed that AOS occurs only in ferrimagnetic materials including synthetic structures [1-4]. However, recently Lambert *et al*. reported that the optical control of the magnetization occurs in ferromagnets including Co-based multilayers thin films and FePtAg-C granular thin film materials [5]. Therefore, the potential mechanisms for AOS in ferromagnetic materials must be reexamined. Here, we report the observation of accumulative magnetic switching from multiple circularly polarized light pulses in FePt-C HAMR media.

2. Experimental

The FePt-30vol%C (hereafter, FePt-C) granular film was deposited by co-sputtering of FePt and C targets on a MgO(001) single crystal substrate by DC magnetron sputtering at 600°C. 10-nm-thick C was deposited as a capping layer at RT. 15-μm-width Hall crosses were used for to measure the ultrashort pulses induced magnetization changes with and without the external magnetic field.

3. Results and discussion

Figure 1(a) shows the magneto-optical image of an initially demagnetized FePt-C granular film after scanning it with both left and right circularly polarized (LCP and RCP) light pulses. The optical pulses induce a net magnetization in the FePt-C and the sign of the magnetization is determined by the helicity of the light. To quantify the optically-induced magnetization changes, we exposed the laser over the Hall cross region. The initial state is remanence after applying saturating magnetic fields of -7 T (Fig. 1c)) and 7 T (Fig. 1d)). Figure 1(c) shows the normalized Hall resistance change after the exposure to RCP, linearly polarized and LCP. For RCP light, the normalized magnetization gradually decreases to zero, then reverses and saturates at about -0.5. This indicates that ~3/4 of the FePt grains switch to the opposite direction. On the other hand, the exposure to LCP light decreases the magnetization to about half of the initial value, corresponding to the switching of ~1/4 of the FePt grains. For exposure to linearly polarized light, the normalized Hall resistance gradually approaches zero. In the case of the opposite initial state (negative saturation) shown in Fig. 1d), RCP, LCP and linearly polarized light exposures result in the same final normalized magnetization of -0.5, 0.5 and zero, respectively. Thus, the magnetization state after exposure to polarized light only depends on the helicity of the light. Fitting Fig. 1(c) and (d), the switching probability by a single pulse is very small, less than 1%. However, accumulating the small switching probabilities results in a continuous change in the magnetization until the final equilibrium state. While an induced magnetization is optically achieved, we only observe fully deterministic switching by the combination of circularly polarized light and a modest external magnetic fields giving a pathway towards technological implementation.

4. Conclusions

In conclusion, we show that the optical magnetic switching for granular FePt films designed for ultra-high-density recording by circularly polarized light is an accumulative effect of multiple optical pulses. This is qualitatively different from the AOS mechanism for GdFeCo but closer to the behavior reported for Pt/Co/Pt structures [6]. The observed AOS in FePt granular media can be described by a statistical model considering a small probability of switching magnetic grains for each light pulse, and these probabilities depend on the helicity of the light. It results in a high degree of alignment of FePt grains of approximately 75% achieved only with multiple circularly polarized optical pulses. We further show that deterministic magnetization switching is achievable by the combination of circularly polarized light and modest external magnetic fields demonstrating that the circularly polarized light can aid the writing in a HAMR-like recording process. This study also suggests that the fully deterministic switching using only AOS for high-anisotropy nanostructures may require more complex structures or application and control of an optically induced magnetic field.

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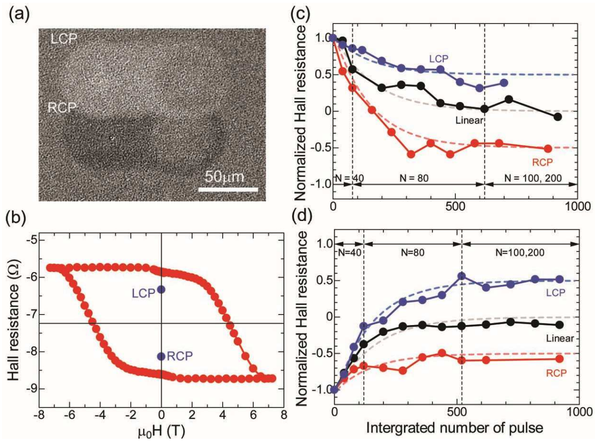

Fig. 1 Magnetization change observed from a FePt-C granular film by exposure to circular polarized light. (a) Magnetic image after exposure to RCP and LCP. (b) AHE curve for the FePt-C granular film. (c,d) Normalized Hall resistance after applying circular and linear polarized light.