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ULTRAFAST HEAT PULSE MAGNETIZATION SWITCHING NEAR COMPENSATION CONDITION IN GdFeCo

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Abstract: Femtosecond laser pulse excitation of multi-sub-lattice rare-earth (RE) transition-metal (TM) ferrimagnets opens the way to trigger ultrafast precessional switching and even all-optical magnetization switching (AOS). This AOS phenomena originated from sub-lattice nature is fundamentally different from conventional magnetic field driven switching mechanism. In this study, we show that the AOS is efficiently work even near compensation composition ratio C_{comp} and compensation temperature T_{comp} that makes hardness of net magnetization (M_{net}) reversal by magnetic field.

1. Introduction

Femtosecond laser pulse excitation of multi-sub-lattice rare-earth (RE) transition-metal (TM) ferrimagnets opens the way to trigger ultrafast precessional switching [1] and even all-optical magnetization switching (AOS). Ultrafast heat pulse act as sufficient stimurous to reverse the magnetization without any external magnetic field [2]. This AOS phenomena originated from sub-lattice nature is fundamentally different from conventional magnetic field driven switching mechanism. It is well known that RE-TM ferrimagnets used in magneto-optical recording may have a magnetization compensation composition ratio C_{comp} and coercivity is drastically increase with closing to C_{comp}. In this study, we show that the AOS is efficiently work even near C_{comp} and compensation temperature T_{comp} that makes hardness of net magnetization (M_{net}) reversal by magnetic field.

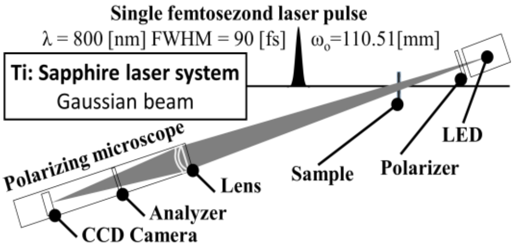

Fig. 1 Inducing and observation systems for ultrafast heat pulse magnetization switching

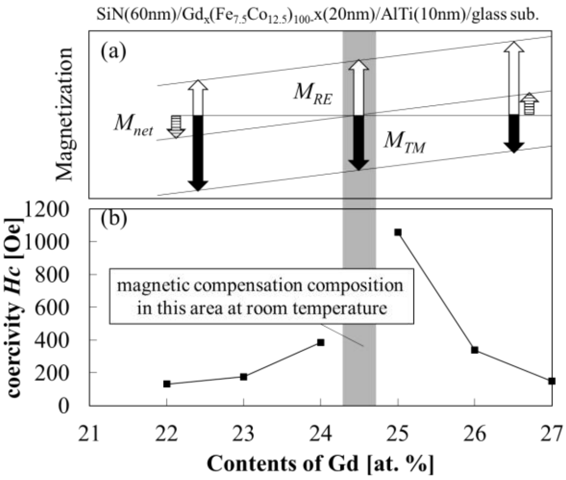

Fig. 2 Gd_x $(Fe_{87.5}$ $Co_{12.5}$ $)_{100\text{-}x}$ compositionl dependence of magnetic characteristics (a) the each magnetization models (b) the coercivity at each composition ratio x at. %

2. Experimental condition

The experiments were performed by placing a sample under a polarizing microscope, where domains with magnetization “up” and “down” could be observed as white and black regions, respectively. To excite the material we used regeneratively amplified pulses from a Ti: sapphire laser at a wavelength of λ= 800 nm, as in **Fig. 1**. Each pulse had a Gaussian intensity profile, with a full width of a half maximum of 90 fs. The magnetic materials studied in this work are 20-nm thick films of the ferrimagnetic RE-TM amorphous alloy $Gd_x(Fe_{7.5}Co_{12.5})_{100\text{-}x}$ (22 < x < 26 at. %). The samples were grown by magnetron sputtering in the following multilayer structure: SiN (60 nm) / $Gd_x(Fe_{87.5}Co_{12.5})_{100\text{-}x}$ (20 nm) / SiN (5 nm) / AlTi (10 nm) / glass sub.

3. The M_{net} independence of ultrafast heat pulse magnetization switching

In order to measure the M_{net} vector dependence of domain sizes created by femtosecond pulse laser excitation, we use the samples of composition ratio near the condition in compensation of sub-lattice magnetizations. Nearby the C_{comp}, each magnetization vectors change dramatically like Fig. 2(a). C_{comp} was exist in the Gd content range of 24 at. % < x < 25 at. % at room temperature, as shown in Fig. 2(b). Fig. 3 shows the compositional dependency of the switched domain sizes under the variety of laser fluences. This results show its little composition dependence. Varying the Gd content x from 22 at. % to 25 at. %, we are able to tune the coercivety

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field *Hc* from below 110 Oe to about 10 times as 1090 Oe. In this composition range, the domain sizes just vary from 150 mm^2 to 1.2 times as 1.8 mm^2 in 2.7 μJ pump-energy. And furthermore, we measured temperature dependence of magnetization switching nearby T_{comp}, of measure M_{net} dependence under the condition of same composition ratio. T_{comp} of the sample (Gd content x=24 at. %) was exist in 215±5 K. Then, created domain sizes are almost same at each temperature (150 < T < 298(room temperature)) in vacuum. In this temperature range, the domain sizes difference is less than 10 %. Thus, created domain size was found as almost independent with $\boldsymbol{M_{net}}$ value under the same condition of laser excitation.

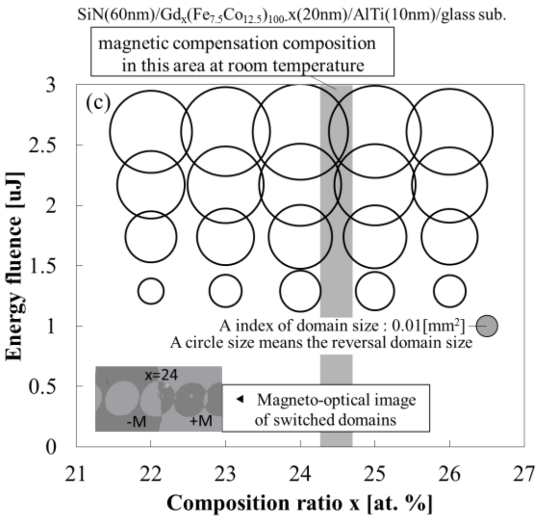

Fig. 3 $Gd_x (Fe_{87.5} Co_{12.5})_{100-x}$ compositionl dependence of swittched domain sizes at each pump light energy and each composition. Inset: magneto-optical image of switched

4. Fluence threshold of ultrafast heat pulse switching

Increasing of energy fluence of incident laser pulse, created domain size was increased drastically. Under the assumption of Gaussian intensity profile in laser spot, fluence threshold W_{ft} mJ/cm^2 was defined as the lowest light energy density inside the reversed domain area. Then, we derived the W_{ft} for this switching phenomena from the results in **Fig. 3** on the assumption that single laser pulse has Gaussian intensity profile and square wave in time direction. Derived values of W_{ft} are in 2.5 ~ 4 mJ/cm^2 and almost the same value of W_{ft} in low pump-intensity. The derived value is almost same order with other report that discussed light color dependency [3].

5. Sub-lattice magnetizations switching with femtosecond pulse laser

The mechanism of heat pulse switching phenomena via strongly non-equilibrium and non- adiabatic way is discuss by experiment and atomic model calculation [2]. Both sub-lattices magnetization rapidly decrease with the laser irradiation at first. Next, the magnetizations of both sub-lattices switch their directions with different time scale and after establishing transient ferromagnetic state [4], then rebuilding their net magnetic moments. According to these foundings, this switching triggered by corresponding to collinear sub-lattice propaties. This is consistent with the features of rather M_{net} independent our result. Then, we can estimate the switching area with fluence threshold W_{ft}.

6. Summery

Femtosecond single laser pulse can excite a magnetization switching. In order to measure the M_{net} vector dependence of domain sizes created by femtosecond pulse laser excitation, we use the samples of composition ratio and temperature near the condition in compensation of sub-lattice magnetizations. As a result, the created domain size was found as almost independent with $\boldsymbol{M_{net}}$ value under the same condition of laser excitation. Then, we can estimate the switching area with fluence threshold W_{ft}.

7. Acknowledge

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8. References

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