ALL-OPTICAL MAGNETIZATION SWITCHING ON GdFeCo/METAL FILMS TRRIGERED BY FEMTOSECOND PULSED LASER

H. YOSHIKAWA[1], S. EL MOUSSAOUI[2], Y. KASATANI[3] and A. TSUKAMOTO[4]

1) Nihon Univ., Chiba, Japan, cshr15001@g.nihon-u.ac.jp

2) Nihon Univ., Chiba, Japan, souliman.el-moussaoui@inl.ecs.cst.nihon-u.ac.jp

3) Nihon Univ., Chiba, Japan, kasatani_yuichi@inl.ecs.cst.nihon-u.ac.jp

4) Nihon Univ., Chiba, Japan, tsukamoto.arata@nihon-u.ac.jp

I. FEMTOSECOND LASER PULSE EXCITED MAGNETIZATION SWITCHING

In order to realize faster recording, we research the magnetic recording by femtosecond laser pulse. All-Optical magnetization Switching (AOS) phenomenon is excited by single femto-second laser pulse without any external magnetic field. This switching is not limited by Ferro-Magnetic Resonance limit unlike conventional magnetic field driven magnetization switching. Additionally, AOS can direct overwrite recording with polarization [1]. It means AOS faster switching and magnetic recording in prospect. Only tens femtosecond laser pulse are sufficient to induce the non-adiabatic and non-equilibrium energy dissipation processes of electron, lattice and spin in metallic thin films and AOS is occurred via these processes [2]. In particular, electronic heating in short time range has important role for it [3]. From this idea, we considered controlling the efficiency of GdFeCo switching with different designed stacked structure which has different electronic energy dissipation character in this short time scale. In this research, we designed GdFeCo/"different electronic specific heat C_{el} metal" films for high efficient AOS recording.

II. EXCITATION OPTICAL SYSTEMS AND FILMS

The GdFeCo thin films were grown on atomically flat glass substrate by magnetron sputtering (DC sputtering for metallic layer and RF reactive sputtering for dielectric SiN layer) following the sequence hereafter: SiN (60 nm) / GdFeCo (10 nm) / metal X (5 nm) / glass sub., (where X = A: GdFeCo, B: AlTi, C: Cu). GdFeCo is one of the famous metal for AOS and magneto-optical (MO) effect. The obtained all the samples had an out-of-plane magnetic anisotropy (squareness ratio ~1). We know the interesting dependency of AOS on the different structured samples as following like GdFeCo (l nm) / SiN (m nm) / AlTi (n nm) ($\{l, m, n\}$ = {20, 0, 10}, {20, 5, 0}, {20, 10, 0} and {30, 5, 10}) [3]. AOS has different dependency from thermo-magnetic nucleated domains, it doesn't simply depend on the total absorbed energy and continuous GdFeCo/AlTi thickness. It suggests AOS especially depends on the electronic energy dissipation process after the absorption as not like usual laser heating process. From this result, we designed the sample A, B and C. The designed GdFeCo thickness, 10 nm is designed similar penetration depth. The GdFeCo surface have twice of absorbed energy at 10 nm from surface after the irradiation. Additionally, we chose different metals which have different electronic specific heat C_{el}. C_{el} depends on γ($C_{el} = \gamma T$) and γ is 5 mJ/mol·K^2 for Fe, 4.7 for Co 1.35 for Al, 3.5 for Ti and 0.688 for Cu [4]. On the other hand, the specific heat C of Fe is 444 J/kg·K, Co is 434, Al is 900, Ti is 519, and Cu is 385 [4].

For AOS excitation, a regenerative amplified laser pulses from a Ti: sapphire laser at a wavelength of λ = 800 nm and the pulse width of 90 fs (FWHM) was used. We shot a femtosecond pulsed laser to these samples perpendicularly. After this excitation, we measured the size of AOS created domains. It was performed by placing a sample under a polarizing microscope, where domains with magnetization "up" and "down" could be observed as "dark" and "bright" regions, respectively.

III. CREATED MAGNETIC DOMAIN SIZE OF METALLIC FILMS WITH SPECIFIC HEAT

As a result, we found that AOS could triggered with lower irradiate laser power in GdFeCo film stucked on smaller C_{el} metal. Fig. 1 shows the irradiated power dependency of the created domain sizes by AOS on each samples. In this figure, open circles means the domains created by AOS and the size of the created domain can be deduced by considering the scale in the inset of the figure. Each AOS on each films increase the size with the irradiated power, because AOS create magnetic domains in the area above an absorbed fluency threshold [5]. Furthermore, the most important result of this experiment is the AOS

HIROKI YOSHIKAWA
E-mail: cshr15001@g.nihon-u.ac.jp
tel: + 81-47-469-5455

created domain size is different on these samples and it realize the relation to C_{el}. The smaller C_{el} metal "Cu" sample C has the smaller threshold than the bigger C_{el} metals. The C dependency didn't is noticed in this result, clearly. If AOS depends on the electronic thermally energy dissipation process in short time scale, we can think the models as follows. After the irradiation by a laser pulse and the absorption at each point of this film. It is thermally equilibrated in metallic layers following the electronic specific heat C_{el} by hot electrons. Therefore, GdFeCo get energy from smaller C_{el} metallic layer. From these, we suggest AOS is able to be triggered by lower irradiate laser power in GdFeCo film stucked on smaller C_{el} metal with short time scale electronic energy dissipation.

ACKNOWREDGEMENT

This work was partially supported by MEXT-Supported Grant-in-Aid for Scientific Research on Innovative Area "Nano-Spin Conversion Science" (Grant No.26103004), MEXT-Supported Program for the Strategic Research Foundation at Private Universities, 2013-2017 (S1311020) and Grant-in-Aid for JSPS Fellows (16J01232).

REFERENCES

1) C. D. Stanciu, F. Hansteen, A. V. Kimel, A. Kirilyuk, A. Tsukamoto, A. Itoh and Th. Rasing, "All-optical magnetic recording with circularly polarized light", *Phys. Rev. Lett.*, 99, 047601 (2007).
2) Radu, K. Vahaplar, C. Stamm, T. Kachel, N. Pontius, H. A. Dürr, T. A. Ostler, J. Barker, R. F. L. Evans, R. W. Chantrell, A. Tsukamoto, A. Itoh, A. Kirilyuk, Th. Rasing & A. V. Kimel, "Transient ferromagnetic-like state mediating ultrafast reversal of antiferromagnetically coupled spins", *Nature*, 472, 205–208 (2011).
3) H. Yoshikawa, S. El Moussaoui, S. Terashita, R. Ueda and A. Tsukamoto, "Magnetic layer thickness dependence of all-optical magnetization switching in GdFeCo thin films", *Jpn. J. Appl. Phys*, 55 07MD01 (2016).
4) The Japan Institute of Metals and Materials, "revised 4th edition Metals data book", p17 [in Japanese] (2004)
5) H. Yoshikawa, S. Kogure, S. Toriumi, T. Sato, A. Tsukamoto, and A. Itoh, "Ultrafast heat pulse magnetization switching near compensation condition in GdFeCo", *J. Magn. Soc. Jpn*, 38, 139 (2014).

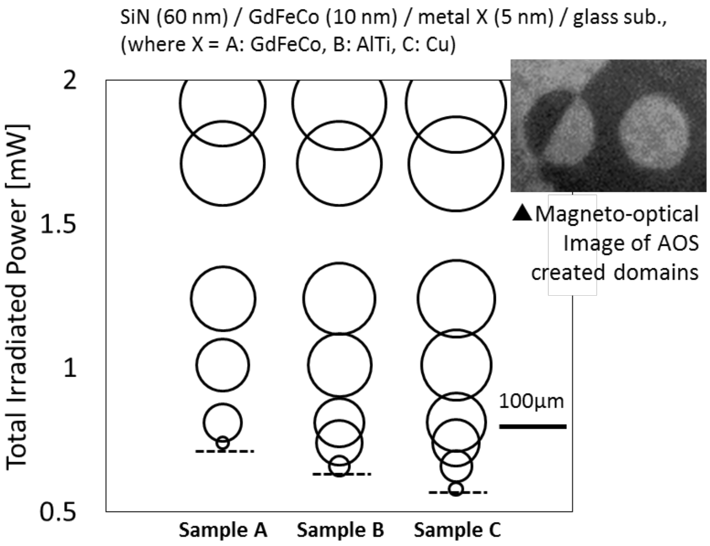

Fig. 1 Irradiated laser power dependence of the created domain size for different sample design A, B, and C. The sizes of circles shows the domains created by AOS and it is deduced by considering the scale in the inset of the imaging.