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Efficient all-optical magnetization switching by optical absorption enhancement with multilayered film structure

*Takeshi Iisaka[1], Hiroki Yoshikawa[1], and Arata Tsukamoto[2]

Abstract: All – Optical magnetization Switching (AOS) is induced by irradiating a ferrimagnetic thin film with light of an extremely short time by a femtosecond pulsed laser[1)]. It strongly depends on the light energy density absorbed in the magnetic layer[2)]. The absorptivity of the magnetic layer was enhanced by the optical interference with multilayered film structure, for gaining the efficiency of AOS. We studied the correlation was enhanced between the effective light absorption characteristic with optical continuum source and the AOS response by ultrashort pulsed light.

1. Intoroductuion

All – Optical magnetization Switching (AOS) can be induced by passing through a ferrimagnetic thin film with light of an extremely short time by a femtosecond pulsed laser without any external magnetic field[1)]. AOS has different excitation principle from conventional field driven magnetic recording. It strongly depends on the light energy density absorbed by the magnetic layer, and its inversion possibility is determined by the threshold value[2)] The absorptivity of the magnetic layer is enhanced by the optical interference with multilayered film structure, for gaining the efficiency of AOS. However, absorption of ultrashort pulsed light is different from absorption of optical continuum source. However, it is not confiremend whether the optical multilayer film in continuous light can be applied even for ultrashort pulsed light. In ferrimagnetic GdFeCo thin film with different optical interference conditions we studied the correlation between the effective light absorption characteristic with optical continuum source and the AOS response by ultrashort pulsed light .

2. Methods

In ultrashort pulse light, electric field vibration is several tens of cycles, it is anticipated that multiple interference can be achieved even with a single ultrashort pulse light in a thin film. We designed the film structure like SiN (*t* nm) / $Gd_{25}Fe_{65.6}Co_{9.4}$ (20 nm) / SiN (5 nm) / glass sub. (t = 20, 40, 60, 80, 100). In this sample group, light is irradiated in the direction perpendicular to the film surface using Spectrophotometer (UV/VIS/NIR) and the reflectance and transmittance spectrum is measured. From the result, the effective light absorption rate of the magnetic layer is estimated. Further, the sample is irradiated with a single pulse laser (FWHM : 90 fs, center wavelength λ : 800 nm), and the formed magnetic domain is observed with a magneto-optical image using a polarization microscope.

3. Increase the effective light absorption of the magnetic layer by the optical interference with multilayered film structure (Optical continnum source)

Fig.1 shows the measurement results of the reflectance Spectrophotometer and the results of the multiple reflection spectrum calculation.(magnetic layer : Fe reference) The reflectance at each SiN layer thickness *t* shows a systematic change. The tendency that the local minimum value transits to the longer wavelength side as *t* becomes larger is also seen in the calculated value. Accordingly, I confirmed the situation that caused Optical multiple interference effect enough.

In each sample, the metal layer is only GdFeCo and the other is a transparent dielectric layer of SiN,glass. From this, light absorption is assumed to be mainly GdFeCo, the effective light absorption of the magnetic layer is estimated from the measurement result of reflectance and transmittance by the spectrophotometer.

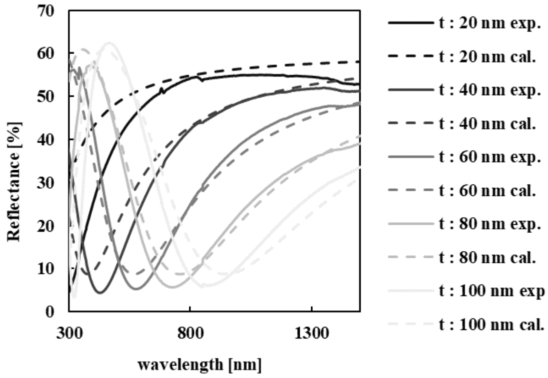

Fig. 1 SiN layer thickness dependence of Reflectance spectrum

1: Department of Electronic Engineering, GST., Nihon-U.　2: Department of Electronic Engineering, CST., Nihon-U.

$$I = R + T + A \quad (1)$$

In EQ. (1), I denotes Incident light, R denotes Reflected light, T denotes Transmitted light, A denotes Absorption. Fig.2 shows the effective light absorption of the magnetic layer when the incident light is taken as 100 % according to EQ (1). Absorption at each SiN layer thickness *t* shows systematic change.

At AOS excitation light wavelength 800 nm, there is a difference in absorption in the range of 35 to 65 %. (Fig.3) It is suggested that up to 65% of input light can be used to induce magnetization switching of AOS.

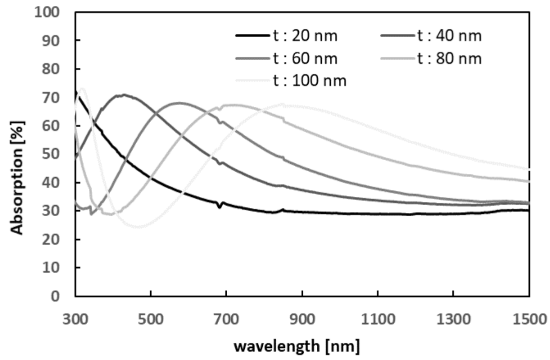

Fig. 2 SiN layer thickness dependence of Absorption spectrum

4. Correlation between light absorption characteristics (optical coutinuum source) and AOS response by ultrashort pulsed light

Each sample is irradiated with the ultrashort single pulse light described above, and the size of the magnetic domain (circle area) to be formed is showed in Fig.4 for each irradiation light intensity. The effective light absorption of the magnetic layer increase in the order of SiN layer thickness t of 20, 40, 60 and 80 nm, and along with this , the irradiation light energy a necessary for switching decrease. From Fig.5, the irradiation energy necessary for switching has a strong correlation with the effective absorption with continuous wave light. It is also suggested that even in ultrashort pulsed light, the effective absorptance increased due to the optical interference effect..

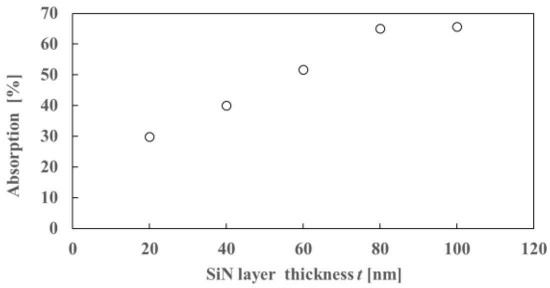

Fig. 3 SiN layer thickness dependence of absorption (λ: 800 nm)

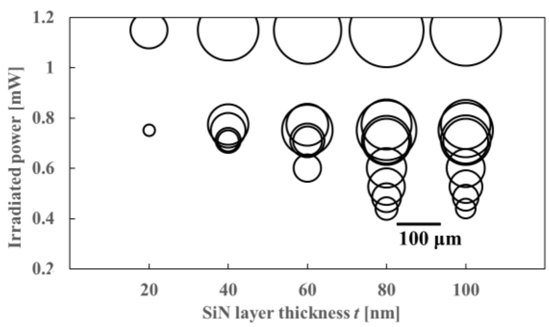

Fig. 4 SiN layer thickness dependence of created domains size by AOS in the film

5. Summary

We studied the correlation between the effective light absorption characteristic by continuous light and the AOS response by ultrashort pulse light . As a result, there is a strong correlation between the irradiation Light energy required for switching and the effective absorption of continuous light. Therefore, it has been experimentally clarified that an optical multilayer film for continuous light can be applied even for ultra short pulsed light, and the then AOS efficiency could be enhanced.

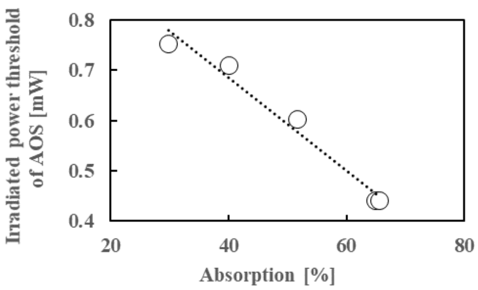

Fig. 5 The correlation between irradiated power threshord of AOS and absorption

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