Challenge to magnetization dynamics observation by Kerr microscope with real-time processing of differential-polarization images

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1. Introduction

In recent years, the functional spin-related devices that apply spin wave and the spin current have been developed. In most cases, these devices has been operated by detecting an electrical signal. However, the electrical signal might reflect not only the magnetic but also other properties, that it is important to verify other detection methods. The detection method by using magneto-optical effect is a useful detection method which has the advantages of non-contact and non-invasive. Additionally, Kerr effect microscope based on the photographic method is useful because it can visualize the two-dimensional spin propagation in a short time. We have been developed the Kerr effect microscope by photographic method[1-4)]. In general, conventional Kerr effect microscope which applies extinction method uses a saturation-image subtraction method[5)] in order to emphasize the magnetic domain image. However, this method has the following problems; a sample with high saturation magnetic field cannot be observed; image deterioration caused by the position deviation of the sample which is affected by magnetic field and thermal expansion and efficiency of light is as low as a few percent. Accordingly, we report the development of Kerr effect microscope for observation of magnetization dynamics by differential-polarization imaging method, which can observe magnetization images in real time.

2. Principle of the differential-polarization imaging method

The schematic diagram of the differential polarization imaging method is shown in the Fig. 1. Light from the lamp illuminates the sample through a relay lens and an objective lens. The reflected light from the sample is imaged by the objective lens and the imaging lens. Images of two orthogonal polarizations are imaged separately by inserting the Glan-Thompson polarizing beam splitter between the imaging lens and the CCD camera. The analog video signals of the CCD camera 1 (CCD1) and the CCD camera 2 (CCD2) are amplified by the differential amplifier. Common background noises which are included in the both CCD camera images like the reflectivity change and so on are canceled by the differential amplifier. Kerr signal is increased by a differential amplifier because each signal is in the reverse phase. For this reason the output signal from the differential amplifier emphasizes the Kerr signal. These signals are captured into PC through the frame grabber with 8 bit brightness resolution. This method has the following advantages; magnetization image can be observed in real time, without application of saturation magnetic field; with no image deterioration according to positional deviation of the sample; the light utilization efficiency is high because of using all of the illumination light forms an image on the two CCD cameras.

3. Experiment

The optical system was arranged to measure the polar Kerr effect. The ample was a GdFeCo thin film with perpendicular magnetization. It was needed to perfectly match the images from each CCD camera to get a correct result. To accomplish this, the position, angle and focus of CCD1 were adjusted by using the pulse motor stage of the XYZθ axis. Electronic shutters of the CCD1 and CCD2 were set to 1/2000 seconds. An observation result of the maze magnetic domain of the GdFeCo thin film which is patterned to 40 × 100 μm is shown in Fig. 2. The images of CCD1 and CCD2 are shown in Fig. 2(a) and Fig. 2(b), respectively. The image of the difference between CCD1 and CCD2 is shown in Fig. 2(c). And the image which is obtained by the conventional extinction method is shown in Fig. 2(d). Domain structure is not observed in the image of Fig. 2(a) and (b) because the brightness change of the magnetic domain is less than the brightness resolution of the frame grabber. Maze magnetic domain structure has been observed in Fig. 2(c). In the differential polarization method, the obtained images contain hardware specific noise such as caused by a CCD camera and signal processing circuitry. To cancel the background noise which is caused by the hardware, the image which is recorded in the metal mirror is subtracted from the measured image. The image observed by the conventional extinction method is shown in Fig. 2(d) as comparison to the measurement result. Both Magnetic domain structure images of (c) and (d) are consistent. In conclusion, the present study has demonstrated that the magnetic domain image can be observed by the differential-polarization imaging method. Image of Fig.2 (d) has been acquired by setting the electronic shutter of the CCD camera to 1/30 seconds. The magnetic domain image was captured by the differential-polarization imaging method with light exposure of 1/67 less than the conventional extinction method. From these results, the Kerr microscope by differential-polarization imaging method is suitable for observation of magnetization dynamics using stroboscopic method. In the conference, the observation on longitudinal Kerr arrangement will be reported.

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Reference

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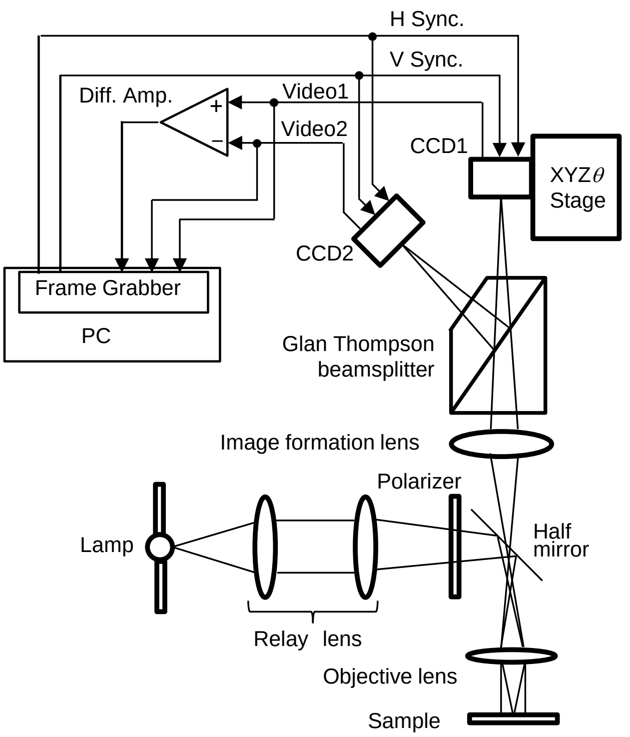

Fig. 1 Schematic diagrams of the differential-polarization imaging method.

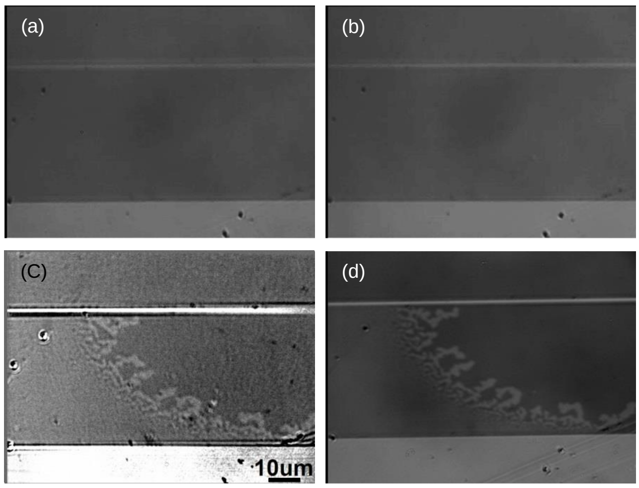

Fig. 2 Observation images and domain images for the GdFeCo thin film pattern (40 ×100 μm). Observation images of (a) CCD1 and (b) CCD2. Domain images of (c) differential-polarization imaging method and (d) conventional extinction method.