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Spin-SEM Observation of Epitaxial Magnetite Films on MgO (001)

Eisaku Kaji*, Agus Subagyo, and Kazuhisa Sueoka

[1]Graduate School of Information Science and Technology, Hokkaido University, Kita-14 Nishi-9, Kita-ku, Sapporo, 060-0814, Japan

*Corresponding author: kaji@nano.ist.hokudai.ac.jp, Phone: +81 11 706 6539, Fax: +81 11 706 7803

Magnetite (Fe_3O_4) thin films have been expected to be highly spin-polarized electrodes for use in spin valvedevices. However, magnetoresistance (MR) measurement of multilayered MR devices has offered unexpected low MR values. Antiphase domain boundaries (APB's) are introduced in epitaxial magnetite thin films grown on MgO substrate to influence spin polarization and interface scatting[1]. The relation between APB's and magnetic induction has been investigated using Magnetic Force Microscope (MFM)[2] and electron holography[3]. Configuration of APB's in the epitaxial magnetite depends on film thickness and post annealing processes[4]. We have investigated APB's on the surfaces by means of scanning tunnelling microscope (STM) and atomic resolution images of APB's have been obtained[5], however, correlation between the surface structure and macroscopic magnetic structure has not been investigated. In this paper, we have used Spin-Scanning Electron Microscope (Spin-SEM) or SEM with Polarization Analyzer (SEMPA) to investigate surface magnetic structure of the films in addition to STM and MFM observation.

Epitaxial Fe_3O_4 thin films of 50nm in thickness wereepitaxially grown on a mechanically polished MgO (001) substrate. The detail of the growth procedures was discussed in the reference [5]. After STM observation which indicated the surface atomic feature of APB's , the sample was annealed at 250°C in air for 4 min and MFM observation was performed prior to introducing the sample into a Spin-SEM chamber. Spin-SEM used in this study is a homemade system. The sample was annealed at 250°C in an ultra high vacuum below $3x10^{-8}$ Pa for 3 hours to change the APB configuration and clean theirsurfaces. Since spin-SEM images were obtained without any sputter cleaning process, it should be possible to observe the surface by STM. The annealing process enhanced perpendicular alignment of the domains of a few hundred nm, which was confirmed by MFM images. MFM images also show relatively large domains of a few mm (Fig. 1(a)). Spin-SEM images shown in Fig. 1(b) (c) indicate that large domain structures were formed with perpendicular magnetization components on this surface. The small structures were not resolved by the spatial resolution limit of present our Spin-SEM system.

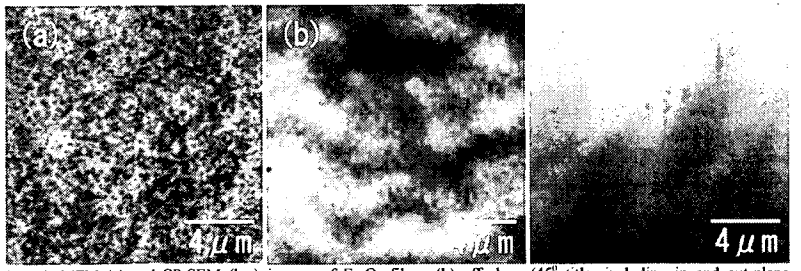

Fig. 1. MFM (a) and SP-SEM (b,c) images of Fe_3O_4 films. (b) off-plane (45° title, including in and out-plane components), (c) in-plan

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XMCD Measurement in CFS and CIS Modes

J.-Y. Kim*[1], H. Jang[2], K.-J. Rho[2], J.-H. Park[2]

[1]Pohang Accelerator Laboratory, Pohang University of Science and Technology, San 31, Hyoja-dong, NamGu, Pohang, 790-784, Korea

[2]Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Korea

*Corresponding author: masson@postech.ac.kr, Phone: +82 54 279 1988, Fax: +82 54 279 1599

XMCD (x-ray Magnetic Circular Dichroism) is a unique tool to investigate the magnetic phenomena of ferromagnetic materials from the microscopic point of view. It has several capabilities, which are not available by another magnetics techniques. First of all it can give us magnetic information with elemental and chemical specificity. The foremost advantage is the capability of the quantitative separation of spin and orbital moment. And it is surface-sensitive because XMCD is usually based on the total electron yield (TEY) measurement. Sometimes it is disadvantageous when we are interested in the bulk property. But if we can control the surface sensitivity, XMCD will be more useful to investigate the surface or interface region of magnetic thin film and multilayer. CFS (Constant Final State) and CIS (Constant Initial State) measurement is very old technique to measure x-ray absorption with kinetic energy selectivity. And it is well known that the penetration depth of electron is highly depends on the electron kinetic energy. It means that we can change the surface sensitivity by selecting the kinetic energy of photo-emitted electrons. In order to measure XMCD in CFS and CIS modes, I modified the data acquisition system of a commercial electron analyser and developed a pulse-magnet to apply a magnetic field to samples. The first measurement was done on the sample of CoFe alloy film with 1 nm thick Al oxide capping layer, which is a part of TMR (Tunnelling Magneto-Resistance) device. The CFS(CIS)-XMCD spectra of Co and Fe *L* edges were successfully measured and compared with the TEY-XMCD. The kinetic energy was selected to be around 100 eV, in order to maximize the surface sensitivity. When compared with TEY-XMCD spectra, which are measured simultaneously, CFS(CIS)-XMCD shows that the orbital moment contribution to the total magnetic moment is different and there is a clear difference in the dichroism of Auger process between Co and Fe. The detailed analysis of the spectra will be shown in the presentation. Because the CFS(CIS)-XMCD spectra reflects the magnetic properties of the interfacialregion betweenCoFe alloy and Al-oxide layers more efficiently, this measurement will contribute to enhance the understanding the role of the interface in magneto-resistance phenomena. All measurements were done at 2A magnetic spectroscopy beamline of Pohang Light Source.