Analysis of orbital angular momentum of valence electrons of Fe(111) by two-dimensional photoelectron angular distribution with circularly-polarized light

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Taking advantage of the phenomenon of circular dichroism in photoelectron angular distribution (PEAD), a stereoscope for atomic arrangement is realized. The azimuthal shifts of forward focusing peaks (FFP) in PEAD pattern obtained by left and right helicity light are found to be the same as the parallax in stereo-view. Since the parallax is also propotional to the angular momentum of photoelectron *m*, which is determined by the initial state and the excitation helicity, the orbital angular momentum of initial state can be deduced. This method was applied to the investigation of the iron surface.

The Fe(111) single crystal sample was cleaned in situ by repeated cycles of Ar^+ bombardment and annealing to 600°C. The surface quality was checked by reflection high energy electron diffraction and X-ray photoelectron spectroscopy. The two-dimensional display-type spherical mirror analyzer was used to obtain PEAD patterns. The circularly-polarized light from helical undulator was incident on the surface along Fe(111) [-1-12] direction 45° off from the surface normal.

Figure 1 is a set of valence band PEAD patterns taken at kinetic energy of E_k = 549 eV. Here the FFP corresponding to first and second layer atoms appear strongly. This photograph shows the bcc structure. Center red circle correspond to the nearest neighbour atom in [111] direction.

Circular dichroism of forward focusing peak rotation is shown in Fig. 2. Photoelectron angular momentum *m* with 1 is dominant in the case of Fe2*p* excitation, while *m* with 2 is dominant in the case of Fe3*d*. A difference of composition ratio of valence band orbital angular momentum in different binding energy can be seen in the figure.

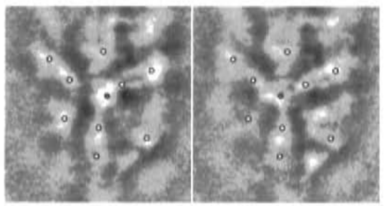

Fig.1 PEAD patterns from Fe valence band using left and right helicity light.

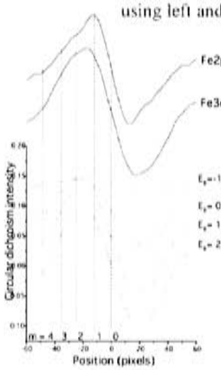

Fig.2 Intensity difference profiles of the [111] FFP (shown as red circle in Fig.1) between left and right polarization excitation.

Magnetic domain observation of crossed permalloy micro pattern using photoelectron emission microscope (PEEM)

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In this decade, the development of nano technology has been helped to improve recording devices. Especially, nano magnetism is directly related to their areal density. The study of shape anisotropy is one of the key information to design the new devices. Therefore it is important not only for pure nano magnetism but also application. Photoelectron emission microscope (PEEM) is a powerful tool to study nano magnetism. The spatial distribution of photo absorption intensity is projected onto the screen with 35 nm spatial resolution. By the combination of MCD technique, we can obtain magnetic domain image on the screen. Here we report a magnetic domain observation of crossed permalloy micro pattern using PEEM SPECTOR at BL25SU of SPring-8.

We prepared a crossed permalloy micro pattern by electron beam lithography and, the shape of micro pattern is varying from square to cross. Fig. 1a) shows the shape of each micro cross, the side length L is fixed to 10 μ m and insection length *l* was varying from 1 to 4 μ m with 1 μ m step.

Here, L of 10 μ m is too large from nano order, however its magnetic property is expected to be similar to nano cross qualitatively[1]. Permalloy was deposited with thickness of 50nm on Si substrate and 1nm Au capping layer was deposited against oxidization. We observed totally 15 magnetic domains for each micro crosses. Figure 1b) shows the magnetic domain image of micro crosses observed by PEEM. Photon energy is set to Ni L edge (852.7eV) and it is obtained by 1Hz quick photon helicity switching mode. Field of view is set to 100 μ m, and it takes 15 min for one magnetic domain imaging.

Two different magnetic domain is obtained for *l*=1. One it vortex domain and other is meta-stable domain[2]. Correspondingly, same two domain is observed for *l*=2 also. The percent of vortex domain is increased from 66% to 93% for *l*=1 and *l*=2 respectively. One possible explanation is that the shape of *l*=2 is close to circular and tend to be vortex domain. The magnetic domain is drastically changed at *l*=3, and vortex is completely vanished. Multi domain or symmetric domain is observed. At *l*=4, domain wall is vanished away and single like magnetic domain is observed. This might be caused by the shape induced anisotropy. This drastic change will be investigated in next experiment on new micro cross sample with smaller step of *l*, and quantitatively explained by micro magnetic simulations.

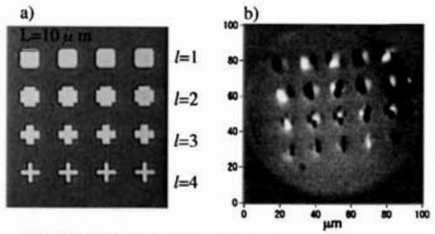

Fig1 a) Permalloy micro cross observed by optical microscope
b) Magnetic domain image observed by PEEM

Reference

1) H. Hoffmann, et al. J. Appl. Phys. 92 (2002) 5463
2) S. Imada, et al. Jpn. J. Appl. Phys. 39 (2000) L585