Magnetic spectroscopy

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Abstract

The research and developement of secondary battery and semiconductor has become valuable recently. For measuring the magnetic properties of the materials used in these areas, magnetic spectroscopy can be used. In this report, the principle of magnetic spectroscopy, such as X-ray circular magnetic dichroism(XCMD), X-ray absorption spectroscopy(XAS), and soft X-ray scattering, was introduced. In addition, an X-ray absorption spectroscopy experiment with a nickel oxide sample was conducted in the 2A beamline of PLS-II.

INTRODUCTION

Recently, the secondary battery and Ai semiconductor has become one of the most prominent industrial areas. Both industries require advanced material science and engineering. Hence, spectroscopy for analyzing materials for memory semiconductors and secondary batteries became important. Magnetic spectroscopy, which uses soft X-ray for spectroscopy.

In this report, an experiment about magnetic spectroscopy(MS), which includes X-ray circular magnetic dichroism(XCMD), X-ray absorption spectroscopy(XAS), and soft X-ray scattering was conducted in 2A beamline of PLS-II.

MAGNETIC SPECTROSCOPY

Magnetic spectroscopy is the type of spectroscopy using linearly or elliptically polarized soft X-ray($20 \sim 3000$eV), which interacts strongly with matters and has low transmission[1]. In the past, MS has been used for researches such as spin-dependent electronic structure, magnetic properties of diluted magnetic semiconductor, and electronic orbital anisotropy. Today, it is used for the verification of the measurements in research on semiconductors and cathode materials for secondary batteries.

For magnetic spectroscopy, the undulator is commonly used as a synchrotron radiation source. One of the advantages of undulator radiation is the tunability of the polarization. This is especially important for XMCD spectroscopy, since it requires left-circularly polarized light and right-circularly polarized X-ray beam. Because molecules in the air scatter soft X-rays and contaminate the sample, creating an ultra-high vacuum environment in every end station is necessary.

Figure 1. shows the magnetic spectroscopy beamline in PLS-II. There are four end-stations in the beamline. In this beamline, the experiment is available at a temperature range of 5K~370K.

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In the first end-station at the middle-left of the picture, the analysis of X-ray beam by photoemission can be conducted.

Next to the first end-station is a chamber for XMCD spectroscopy. In that end-station, the difference spectrum between two X-ray absorption spectra is obtained by left circularly polarized light and right circularly polarized light under magnetic field. The measurement of XAS is conducted by the total electron yield, which measures all excited electrons, or by the fluorescence yield, which measures the fluorescent photons by detector. The total electron yield has a short probing depth(~15nm), so it is used for surface probing. On the other hand, the fluorescence yield with probing depth ~100nm is used for bulk probing. XMCD is used to obtain magnetic information about the material, such as spin and orbital magnetic moment.

The third end-station is for soft X-ray absorption spectroscopy. Soft XAS enables the local geometric and electronic structures of materials to be determined by measuring the absorption spectrum as a function of incident photon energy. In this station, quick measurement of the sample is possible, as it takes approximately 3 hours to recover the vacuum environment by baking.

The last end-station is a chamber for soft X-ray scattering. The diffraction pattern of the sample is detected by two diffractometers.

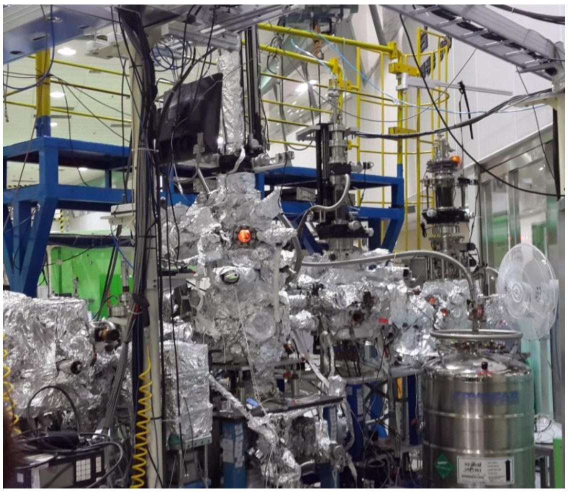

Figure 1: Photograph of magnetic spectroscopy beamline in PLS-II.

EXPERIMENTS

In this section, X-ray absorption spectroscopy measurement of nickel oxide(NiO) sample was conducted. The sample is mounted between two magnets during the XAS experiment(see Fig. 2). The position of X-ray beam can be detected by fluorescent material. The polarization of X-ray beam was aligned by changing the magnetic field of the undulator. Figure 3 shows the interface of control system of XAS undulator. The gap, taper, and magnitude of the magnetic field of the undulator can be controlled through this system.

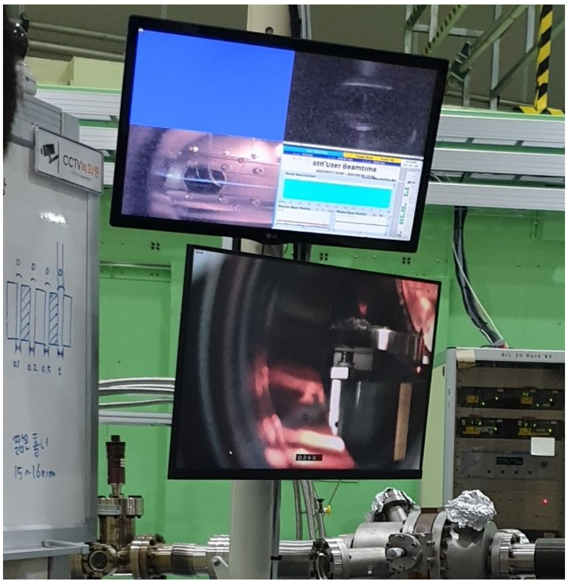

Figure 2: The photograph of sample placed between magnets for XAS experiment.

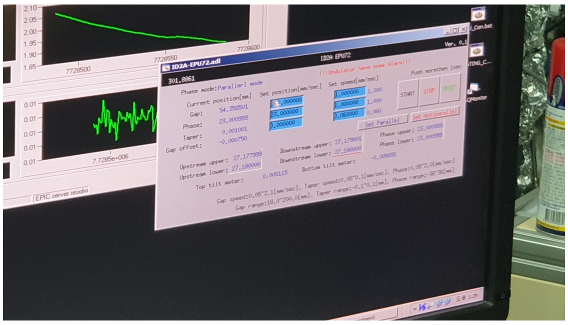

Figure 3: The interface of control system of XAS undulator.

Figure 4 shows the XAS spectrum of oxygen and nickel respectively. The peaks in the XAS spectrum indicate the unoccupied electronic states of atoms. Thus, by comparing the spectrum with the previous measurement data, the chemical states of the sample can be identified.

CONCLUSION

In this report, the principle of magnetic spectroscopy, which plays an important role for the research of secondary battery and semiconductor, was presented. In addition, an X-ray absorption spectroscopy experiment using a nickel oxide sample was demonstrated in the 2A beamline of PLS-II.

REFERENCES

[1] Y. Kim, *Lecture note on Soft X-ray spectroscopy and application to AI semiconductors and rechargeable batteries*, Division of Advanced Nuclear Engineering (DANE), POSTECH, Pohang, Korea, Apr. 2025

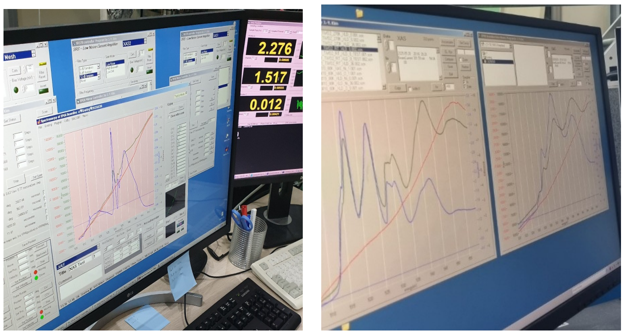

Figure 4: The XAS spectrum of (a)oxygen and (b)nickel respectively