Development of a method to measure molecular frame EELS cross sections

N. Watanabe[1], **S. Yamada, T. Hirayama, A. Seki, D. Suzuki, and M. Takahashi**

IMRAM, Tohoku University, Katahira 2-1-1 Aoba-ku Sendai 980-8577, Japan

Synopsis We have developed an apparatus for electron-ion coincidence experiments to examine high-energy electron scattering cross sections in molecular frame. By using the apparatus a preliminary experiment is performed for inner-shell excitations of N_2 at incident electron energy of 1.5 keV. The experimental result for the $1s \rightarrow \pi^*$ excitation clearly shows that the electron-scattering cross section for the fixed-in-space N_2 molecule has successfully been obtained.

Electron-energy-loss spectroscopy (EELS) has been used as a powerful tool to investigate the electronic structures and excitation processes of atoms and molecules. A close examination of the momentum-transfer dependence of the electron-scattering cross sections allows one to infer the nature of excitation processes of interest as well as the symmetry and spatial extent of orbitals to which the target electron is excited [1]. It should be noted, however, that for molecules, what can be observed in EELS experiments is only the average value over all the orientations of the gaseous targets and that the spherically averaging results in substantial loss of information on electronic excitation dynamics and target electronic structure. To remove ambiguities in the analysis of the spherically averaged EELS cross sections, we have recently developed a method to perform molecular-frame EELS experiment by means of ion fragmentation of axial recoil. In this contribution we report the details of our apparatus developed and preliminary experimental results.

A schematic of our experimental setup is shown in Fig. 1. The spectrometer consists of an electron gun, a molecular beam source, a hemispherical electron analyzer, and an ion imaging spectrometer equipped with a position sensitive detector. A pulsed electron beam is crossed with a gas jet expanded from a nozzle. The electrons scattered at a particular angle of θ are energy analyzed using the hemispherical electron analyzer. Subsequently, ion extraction electric-field is applied to the scattering region to collect fragment ions produced by the electron impact. Within the axial recoil approximation, the direction of the ion recoil-momentum coincides with the molecular axis at the moment of the electron scattering.

By using the electron-ion coincidence spectrometer we have performed a preliminary molecular-frame EELS experiment for inner-shell excitations of N_2 at incident electron energy of 1.5 keV. The EELS cross section thus obtained for the $1s \rightarrow \pi^*$ excitation at $\theta = 6°$ is shown in Fig. 2, where it is plotted as a function of the angle ϕ_K of momentum transfer vector $\boldsymbol{K}$ from the molecular axis. Under the experimental conditions employed, the inner-shell excitation can approximately be regarded as dipole-transition. In this case it is expected from scattering theory that the EELS cross section is proportional to $\sin^2\phi_K$. As can be seen in Fig. 2, the experiment shows good agreement with the expectation and this clearly indicates that the ϕ_K dependent EELS cross section has successfully been obtained.

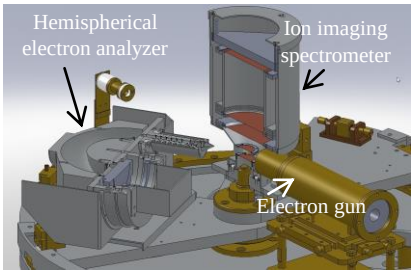

Figure 1. Schematic of our experimental setup.

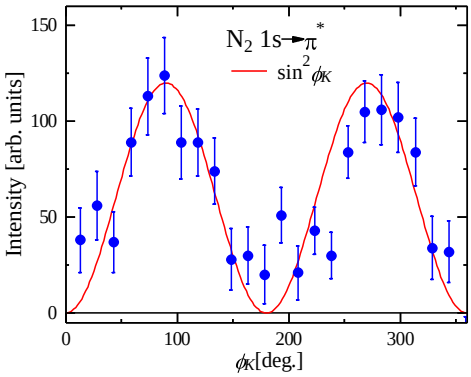

Figure 2. Molecular frame EELS cross section for the $1s \rightarrow \pi^*$ excitation of N_2.

References

[1] M. Inokuti 1971 *Mod. Phys.* **43** 297

[1] E-mail: noboru@tagen.tohoku.ac.jp