A space-charge-effect-compensated electron monochromator for electron-impact multi-coincidence measurements

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Synopsis A new experimental apparatus was developed for electron-impact multi-coincidence measurements at high energy resolution. A new monochromator which was designed to take the space charge effect into account was developed. It is shown that the new monochromator is able to produce a monochromatized electron beam with high current and a high energy resolution which is sufficient to carry out the multi-coincidence measurements.

Dissociative ionization of molecules by low-energy electron impact is a fundamental process of great importance which produces reactive fragments driving pursuing reactions [1]. A detailed information on the electron-impact dissociative single ionizaiton of a molecule AB as

$$\mathrm{AB} + e_i^-(E_i) \longrightarrow \mathrm{AB}^+ + e_s^-(E_s) + e_e^-(E_e) \quad \hookrightarrow \mathrm{A} + \mathrm{B}^+(E_{ion}), \qquad (1)$$

where E_j $(j = \mathrm{i, s, e, or\ ion})$ is the kinetic energy of the particle, can be studied by coincidence detection of the three particles, e_s^-, e_e^-, and B^+. Only recently such experiments have been achieved [2] although insufficient energy resolution prevented complete determination of the dissociation dynamics. In the present study, we developed a new experimental apparatus for the coincidence measurements of e_s^- and e_e^- together with B^+ produced in the reaction (1) with a higher energy resolution.

The present apparatus utilizes an electron monochromator which suffices both high resolution and high current for the monochromatized electron beam. The new monochromator was designed taking into consideration of the space charge effect (SCE), the effect resulted from mutual repulsion of electrons in the beam.

Before constructing the new monochromator, we have studied the SCE in the electron monochromator using a typical spherical type apparatus. For the study of the SCE, we measured transmitted electron current of a hemispherical energy selector as a function of injecting electron current I_{in}, which is one of the key parameter determining the strength of the SCE. Trajectories of electrons in the selector under the SCE were also calculated and compared with the measurements. From the comparison, two main effects of the space charge were found: i) the SCE enlarges the focusing deflection angle of the selector; ii) the SCE enhances the energy dispersion of the selector. The results imply that the electron monochromator can produce the electron beam with a small energy width in the high current condition when the effect i) is compensated.

Following the above idea, we constructed the two-stage cylindrical-type electron monochromator with the deflection angle adjusted so that the SCE could enhance the energy dispersion without degrading the focusing property. In order to test the performance of the new monochromator, we measured the electron current I_{out} and the energy width ΔE_M of the beam transmitting the selector as a function of I_{in}. As shown in Fig. 1, both of the values of I_{out} and ΔE_M change drastically due to the strong SCE. It can also be found that an optimal condition exists where the maximum of I_{out} and the minimum of ΔE_M coincide due to the achievement of the focus of the electron beam in the strong SCE condition. According to Fig. 1, the incident electron beam with $I_{out} \approx 30$ nA and $\Delta E_M \approx 20$ meV is available with the present monochromator, which is sufficient to carry out the multi-coincidence measurements.

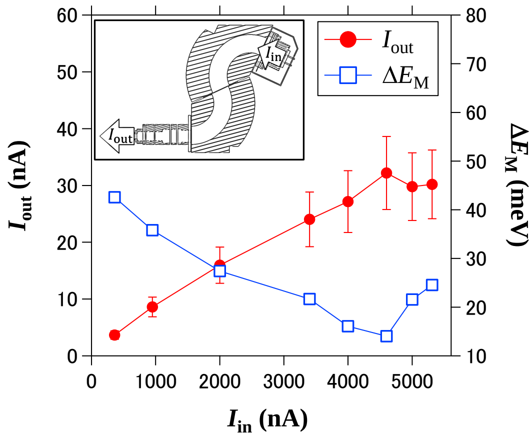

Figure 1. The injected electron current dependence of monochromatized electron beam current I_{out} and its energy width ΔE_M. The left vertical axis represents I_{out}, the right ΔE_M.

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References

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