Design of the suprathermal ion mass spectrometer (STIMS) and experimental study of ion scattering characteristics at foil

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In ionospheres of non-magnetized planets, e.g., Venus and Mars, planetary ions directly interact with the solar wind magnetic field due to the absence of intrinsic magnetic fields. These ions are accelerated up to suprathermal energies and escape from the planetary ionospheres, which is so-called ion pickup that is one of the processes of planetary ion escape. This process is an interesting topic of space physics around the non-magnetized planets. As for major ions such as H^+ and O^+, three-dimensional ion velocity distributions have been successfully obtained by in-situ observations. There is, however, a problem that conventional observation techniques have not been sufficient to derive precisely three-dimensional velocity distributions of heavier molecular ions such as CO^+/$N_2{}^+$ and $CO_2{}^+$. This problem is caused by low mass resolutions of the conventional space-born mass spectrometers. In order to improve the mass resolutions, we have been designing a suprathermal ion mass spectrometer (STIMS) for future in-situ observations of the three-dimensional ion velocity distributions around the planetary ionospheres.

The STIMS consists of (a) a top-hat type electrostatic analyzer (ESA) and (b) a time-of-flight (TOF) analyzer. A field of view of the STIMS is about 4 PI sr per a half spin of spin-stabilized spacecraft. A target energy range is from 0.1 to 300 eV, which corresponds to suprathermal energies, and a mass range is from 1 to 50 amu. We aim to achieve an energy resolution (deltaE/E) that is better than 5%, and a mass resolution (M/deltaM) that is over 10.

(a) An energy analysis of the STIMS is carried out with the top-hat type ESA, which consists of two dome-shaped electrodes: inner and outer dooms. In order to deflect incident positive ions by 90 degrees, a sweeping negative voltage is applied to the inner dome, while the outer dome is grounded. Only ions that drift around a center radius of the two domes can enter the TOF analyzer. Between the ESA and the TOF analyzer, the ions are accelerated by -10kV.

(b) The TOF analyzer of the STIMS is mainly made up of three elements: carbon foils, guiding electrodes and micro-channel plate assemblies (MCP). TOFs are obtained from time differences between start and stop signals. Just as the accelerated ions get through the foil, secondary electrons are emitted. Guided by the electrodes, the emitted electrons arrive at the start MCP and generate the start signals. In the same way, the stop signals are generated when the ions arrive at the stop MCP.

The profiles of TOF in the STIMS are simulated with SIMION. Generally, after penetrating the foil, particle velocities decrease by a few percent and, at the same time, charge exchange and/or dissociation could occur. Whether or not the charge exchange and/or the dissociation occur, it is possible to obtain the particle TOFs when velocities of all particles are equal after penetrating the foil. In this simulation, therefore, it is assumed that the velocities of all particles are equal after penetrating the foil.

This assumption seems to be theoretically valid, but it is necessary to confirm experimentally. Thus, our group are now conducting experimental research so as to investigate following characteristics of the particles after penetrating the foil: (1) particle velocity distributions, (2) angular scattering distributions, (3) charge exchange type and rate, (4) dissociation type and rate. We have been designing an experimental device. In the device, two types of MCPs are applied: one-dimensional position-sensitive MCP for the detection of the particle angular scattering distributions, and high-speed response (TOF) MCP for the identification of the particle velocity distributions. We are planning to utilize our low-energy beam line facility in our laboratory, which is able to emit several types of ion beams such as H^+, N^+, Ar^+, $N_2{}^+$ and $CO_2{}^+$ with 10keV.