

地球・惑星電磁気圏探査を目指した高質量分解能 ToF 型イオン質量分析器の設計 Design of a ToF type ion mass spectrometer with high mass resolution for future planetary in-situ observations

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Many investigations of ion three-dimensional velocity distribution functions (VDFs) have been conducted with spacecraft-borne ion mass spectrometers (IMs) to clarify plasma dynamics around terrestrial/planetary ionospheres and magnetospheres. According to numerical simulations, it has been considered that molecular ions exist around ionospheres of non-magnetized planets (e.g. Kransnopolksy et al., JGR, 2002). But there is a problem that conventional time-of-flight (ToF) type IMs applying carbon foils (CFs) require high acceleration voltages to measure molecular ion VDFs with high mass resolution. Generally, acceleration voltages are limited due to sizes of power supplies which can be applied to spacecraft. A limitation of acceleration voltages is critical for this problem because mass resolution depends on the acceleration voltages. Therefore, developments of IMs that can also measure VDFs of the molecular ions without high acceleration voltages are necessary for future investigations of plasma dynamics around the ionospheres of non-magnetized planets.

Our ToF type IM is supposed to be installed on spin-stabilized spacecraft. It consists of two analyzers: a top-hat type electrostatic analyzer (ESA) and a ToF analyzer. Firstly, the ESA discriminates kinetic energy per charge (E/q) of incident ions by applying sweep voltages to spherical electrodes. Secondly, information of ion velocities (v) can be derived from ToFs of accelerated ions with a high uniform energy (E_{acc}) at the ToF analyzer. Finally, from a relationship between E_{acc}/q and v , we can get information of incident ion mass per charge (M/q).

In this study, we designed the ToF analyzer by adopting new applications, conversion surfaces (CSs), instead of the conventional applications, the CFs, to realize measurement of the molecular ion VDFs with high mass resolution. A particle ToF is defined as a time difference between a START signal and a STOP signal. In the case of our ToF analyzer, secondary electrons emitted by collisions of the incident positive ions with the CSs, are treated as the START signals. The STOP signals can be generated by only reflected particles which can pass through a slit. Due to the collisions, charge-exchange reaction occurs, and most of the incident positive ions are converted into neutral particles. Electrode structures which produce linear electric fields (LEFs) are adopted to make it possible to analyze ToFs of reflected positive and negative ions with high accuracy. In the case of molecular ion collisions, dissociative reaction occurs with high probability, and the molecular ions split up into positive, negative, and neutral particles. Thus, three types of STOP signals may be generated in response to one START signal. Our ToF analyzer can also identify positions where the incident ions collide with the CSs by detecting incident positions of secondary electrons on START micro-channel plate (MCP). We firstly designed simple electrode model of the ToF analyzer with SIMION. Secondly, we analyzed a specification of the ToF analyzer with numerical simulations. As a result, we finally concluded that mass resolutions of the reflected positive ions are high enough to identify CO_2^+ and HCO_2^+ respectively at full width half maximum.

In this presentation, we will show numerical simulation results of the ToF analyzer, and will describe its total specification.

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