Numerical design of double-shell electrostatic energy analyzer with hemispherical field of view

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The magnetospheres of the Earth and planets consist of regions with various structures due to the influence of the solar wind. In order to understand the physical phenomena occurring in these regions, it is important to obtain three-dimensional(3-D) velocity distribution functions through in-situ particle measurements. While the 3-D velocity distribution functions have been acquired by the analyzers with a fully planar field-of-view(FOV) on a spin-stabilized satellite, it is unrealistic to acquire the precise 3-D velocity distributions when this type of the analyzer is mounted on a three-axis stabilized satellite. Therefore, a hemispherical FOV analyzer is required to be mounted on a three-axis stabilized satellite for acquiring the 3-D velocity distribution functions.

The miniaturization of satellites has been promoted in these decades, and it is necessary to reduce the size and weight of particle analyzers for these small/micro satellites. In the case of observing ions and electrons in the conventional technology, two separate analyzers must be installed, one for ions and the other for electrons. However, it could be difficult to mount two analyzers due to the restriction for small/micro satellites. If these two sensor heads of the ion and electron analyzers can be combined into one, it is possible to reduce the total instrument size, weight, and power for the ion and electron observations on small/micro satellites. We have developed a hemispherical FOV double-shell electrostatic energy analyzer which enables to observe ions and electrons by one sensor head on a three-axis stabilized satellite.

The hemispherical FOV double-shell electrostatic energy analyzer is cylindrically symmetric and consists of an FOV deflection system, an ion/electron separator, a double-shell electrostatic energy analyzer, and detectors. The FOV deflectors have electrode shapes that achieve a hemispherical FOV of 2π [sr] by applying a high voltage to the upper or lower electrode, depending on deflection angle. The ion/electron separator is applied by a negative voltage so that ion and electron trajectories are separated into each of the analyzers.

The double-shell analyzer consists of an outer dome, a middle dome, and an inner dome. Ions enter the gap between the outer and middle domes, and electrons enter between the middle and inner domes. A negative voltage is applied only to the middle dome to produce an electric field that allows each species with appropriate energies to pass through the electrostatic energy analyzer.

Based on this instrumental concept, numerical simulations have been performed using a charged particle orbit calculation software, SIMION, and the performance of the hemispherical FOV double-shell electrostatic energy analyzer has been under evaluation. As evaluation criteria, the energy-elevation angle characteristics are particularly subject to investigation. The energies and incident angles of the particles that could reach the detector and the energy and angular resolutions should be evaluated. We report the simulation results of the performance for the hemispherical FOV double-shell electrostatic energy analyzer.

Keywords: Low-energy ion observation, Low-energy electron observation, Particle instrument, Electrostatic energy analyzer, Numerical design