國立成功大學電漿與太空科學中心
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Ion Measurements of Ionosphere Plasma in Space Plasma Operation Chamber

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演講地點：綜合大樓一樓 R.48111

演講日期：10 月 23 日(四) 10:00AM

Abstract

The Earth's ionosphere consists of plasma and neutral particles in the electric and magnetic field environment. Although the ionospheric plasma is produced mainly by ionization of neutral particles by solar radiation, the ionosphere couples strongly with the lower atmosphere, the thermosphere, and the magnetosphere in exchange of plasma and neutral particle density, momentum and energy. The plasma composition and energy distribution function and drift motion in the ionosphere are also related to the structure of electric and magnetic fields and current systems as well as physical processes such as particle collisions, Joule heating and plasma irregularities. Thus, plasma measurements are critical for understanding the ionospheric environment.

In situ ion measurements in the ionosphere are mostly done with retarding potential analyzers (RPA) onboard satellites and sounding rockets. However, like most of the electrostatic analyzers such as Langmuir probes, the electrode contamination can be a serious problem for the RPA measurement. The contamination layer acts as extra capacitance and resistance and leads to distortion in the measured I-V curve, which leads to erroneous measurement results. There are two main effects of the contamination layer: one is the impedance effect and the other is the charge attachment and accumulation due to the capacitance. The impedance effect can be reduced or eliminated by choosing the proper sweeping frequency. However, for RPA the charge accumulation effect becomes serious because the capacitance of the contamination layer is much larger than that of the Langmuir probe of similar dimension. This effect causes the measured ion drift velocity

(ion temperature) to be higher (lower) than the actual values. The error caused by the RPA electrode contamination is expected to be significant for sounding rocket measurements with low rocket velocity (1~ 2 km/s) and low ion temperature of 200-300 °K in the height range of 100-300 km.

A contamination-free retarding potential analyzer was designed for sounding rocket missions and was placed in the Space Plasma Operation Chamber (SPOC), which was constructed at NCKU in 2009, to measure the ion energy distribution in SPOC. SPOC is a research plasma device designed to produce plasmas similar to those in the ionosphere. SPOC has been used for studying space plasma processes and for the calibration and test of satellite/rocket-borne instruments. It is a cylindrical chamber of 2 meters in diameter and 3 meters in length. The SPOC plasma is produced by two back-diffusion type plasma sources installed at the center of the chamber side doors. The sources produce ions of controllable drifting energy from a few ten eV to several hundred eV. These ions, together with the thermal electrons emitted from Nickel cathodes, collide with neutral molecules of 10^{-4} Torr pressure in the chamber and form the plasma environment. The plasma density varies from 10^{3} to 10^{6} cm^{-3}, and the neutral density is ~10^{12} cm^{-3}. Electrons have Maxwellian distribution with temperature of 1000-3000 °K. The ion distribution has two components; one is a drift-Maxwellian component with temperature close to the neutral particle temperature (room temperature), and another is a small ion beam component.

In this presentation, I will discuss the measurements associated with the RPA contaminated electrodes based on theoretical analysis and experiments performed in SPOC. The SPOC machine details and its capabilities on plasma experiments and space environmental tests are described. The spatial and energy distributions of the thermal and beam ion components in SPOC measured by a contamination-free RPA system is presented. The electron temperature and density spatial distributions measured by a Langmuir probe are also shown.

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