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Space Plasma Operation Chamber of National Cheng Kung University, Taiwan

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Abstract: Space Plasma Chamber which can be used for basis plasma experiments , development of space plasma Instruments, vacuum test and performance check of tiny satellite. The diameter and length are 2m and 3m respectively. The Chamber so far has one turbo molecular, and cryo pump for vacuuming. Neutral gas is injected to the plasma Chamber, with a mass flow controller. One quadrupole type mass spectrometer is attached. Two kinds of gas, Usually N_2 and O_2 can be injected Plasma source consist of one mesh grid in front of BaO coated Nickel wire, and plate, which was developed more than 50 years ago in Japan by K. Takayama. Maximum electron density, and electron temperature which are produced by one plasma source so far is 10^5 eles/cc, and 1000-3000 K respectively under the nitrogen gas of 10^{-4} Torr.
Ion temperature is almost equal to neutral temperature (room temperature). Ion beam whose balk velocity is close to grid potential exist. This suggests that, neutral particles are ionized just before the grid. The chamber has a movable mechanism for the plasma sensor to be able to measure spatial distribution of electron density and temperature.

1.Roles of the chamber

When we first start space development, it is essential to have a space chamber to partly simulate space situation in neutral density, and plasma. In order to finally accommodate instrument in satellite, to make sure the performance of the each component, sub system, and whole satellite in the vacuum. Plasma instrument need s to be tested in plasma environment on the ground from many aspects. Now tiny satellite (minimum Unit; 10cm x 10cm x 20cm) will be able to play major role when it is launched as constellation, meaning that many satellites are distributed in space. As a first step, we are trying to launch tiny satellites constellation to understand the coupling between lithosphere-atmosphere-ionosphere, and magnetosphere. Therefore the role of space plasma chamber is again becoming important. Even not large chamber might be good if it has enough capability to accommodate tiny satellite inside for vacuum test and for performance test. We developed a chamber of 2m in diameter and 3 m in length in National Cheng Kung University, Tainan, Taiwan. We introduce below the chamber briefly for the scientists and engineers who would like to use the chamber.

2.Space Plasma Operation Chamber at NNKU

SPOC is a cylindrical stainless-steel (SUS-304) chamber with dimension of 2 meters in diameter and 3 meters in length as shown in Fig. 1. One SPOC door can be totally opened, so that even large spacecraft can be put inside SPOC. On another door, a subsidiary small chamber is mounted. The small chamber, isolated by a valve to the main chamber, is installed with a linear-motion feedthrough, a vacuum breaker valve, a small door and a mechanical pump. Instruments can be moved from the main chamber into this small chamber by the linear-motion feedthrough during vacuuming. After the valve between main chamber and the subsidiary chamber is closed, the subsidiary chamber vacuum can be released separately and manual operation to instruments can be done within this small chamber. The manipulated instrument can be sent back into the main chamber after vacuuming the subsidiary chamber and opening the valve to the main chamber. This small chamber can be also used for the D region chemical simulations by putting differential pumping system. There are totally 16 flanges of size CF-200 and several small size flanges distributed uniformly on SPOC (including sizes of CF-35 and CF-16 sizes). Different vacuum feedthroughs including D-sub, BNC, MHV, high current and high voltage copper connectors are installed on several flanges (connectors including 5 BNC, 5 MHV, 3 copper rod connector, 2 D-sub-9pin, 2 D-sub-15pin and 2 D-sub-25pin). Environment inside SPOC can be observed through 4 glass windows. A moving system and a rotation platform of 1 kilogram weight limit are installed in the chamber, so that instruments can be moved along the chamber axis and the vertical direction, and rotation of instruments can be achieved. The moving system is controlled by the man-machine interface on the SPOC control station. The feedback circuit is designed so the instrument position can be accurately known with a precision level of millimeters. Figure 2 shows the SPOC connection system. The vacuum in SPOC is achieved by 4 pumps. Two 3000 l/s cryogenic pumps (CP1 and CP2) and one 2200 l/s turbo-molecular pump (TP1) are mounted on one lateral side of SPOC. All these pumps and SPOC are connected through valves to a stainless-steel pipe line that is connected to one oil-free 200 l/s mechanical pump (DP+BP). One Pirani vacuum gauge (PG1) and two ionization vacuum gauges (IG1 and IG2) are mounted at different positions on the top of SPOC. Because of the position of pumps, a small pressure gradient exists in SPOC. Pressure measured by the front ionization gauge (IG1) is usually 10-15% lower than the back ionization gauge (IG2). The pressure values measured by the gauges are monitored in the SPOC control station. Pumps and valves are controlled manually on the control station. A safety circuitry is programmed so that appropriate valves are automatically closed in case of unexpected pressure increase or vacuum failure. With all pumps in operation, the pressure in SPOC can reach ~10^{-8} Torr in 2 days. With only the turbo-molecular pump backed by the mechanical pump in operation, the background pressure (~10^{-6} Torr) for plasma generation can be achieved in half a day as shown in Fig. 3. Different gases can be injected through a flow-control valve and a flow meter (MFC in Fig. 2) into SPOC. By controlling the gas flow rate during pumping, the pressure in the chamber can be maintained at specific values (during plasma generation, usually $2x10^{-4}$ Torr is maintained). The flow-control valve connects SPOC to a small gas reservoir chamber. Different gases can be mixed in this reservoir before injection. The gas mixing ratio is roughly determined by a pressure gauge (VG1) mounted on the gas reservoir, and can be checked precisely in SPOC by a residual gas analyzer (neutral mass spectrometer) mounted on the top of SPOC. A measurement result of the residual gas analyzer when there is no additional gas injection is also shown in Fig. 3.

3. Various experiments done before

Spatial distribution of electron temperature and density were surveyed. One back diffusion type plasma sources is operated to get fundamental information. Maximum electron density produced is about 10% els /cc, and electron temperature is 1000-3000 K. A new instrument, TeNeP which based on original Electron temperature Probe was developed to measure both electron density and electron temperature successively by one experiment. Energy distribution of thermal and non-thermal electrons was measured by an instrument, which combines second harmonic method and channel electron multiplier. The effect of electrode contamination was extensively studied. The thickness of the contamination layer was first measured (20-80 nm). This allowed us to estimate capacitance of contamination layer more realistically. Payload of sounding rocket was also tested before delivery. Figure 4 shows an example of the performance test of sounding rocket payloads in SPOC. This payload was accommodated in a NSPO sounding rocket #10. The circuit performance under the vacuum condition and possible interferences between instruments are checked. Pico satellite which was made by Electric Engineering group was also tested. Drift plasma generator is under development The devise will help to check the performance of Plasma Drift Meter, which is one of the essential instruments for the study of ionosphere dynamics.

4. Concluding remarks

SPOC at NCKU was constructed by using most advanced vacuum technology. The SPOC can be easily operated by a student without any assistance. We hope that the SPOC can be open to foreign scientists, especially to Asian countries, in the near future.

References

Fang, H. K., K.-I. Oyama and C. Z. Cheng, Electrode Contamination Effects of Retarding Potential Analyzer, accepted for publication Rev. Sci. Instr. 2013

Fang, H. K., K.-I. Oyama, and C. Z. Cheng, Plasma measurements in Space Plasma Operation Chamber (SPOC), accepted for publication, Chin.J. Phys.(Taipei).

Oyama, K.-I.,Y. W, Hsu, G. S. Jiang, W. H. Chen , H. K. Fang, C. Z. Cheng and W.T. Liu, Electron temperature and density probe for small aeronomy satellites, under communication Rev.Sci.Instr., 2014
Fang, H. K., Ion measurements of ionosphere plasma in Space Plasma Operation Chamber(SPOC), Oct 20154, Phd Thesis.

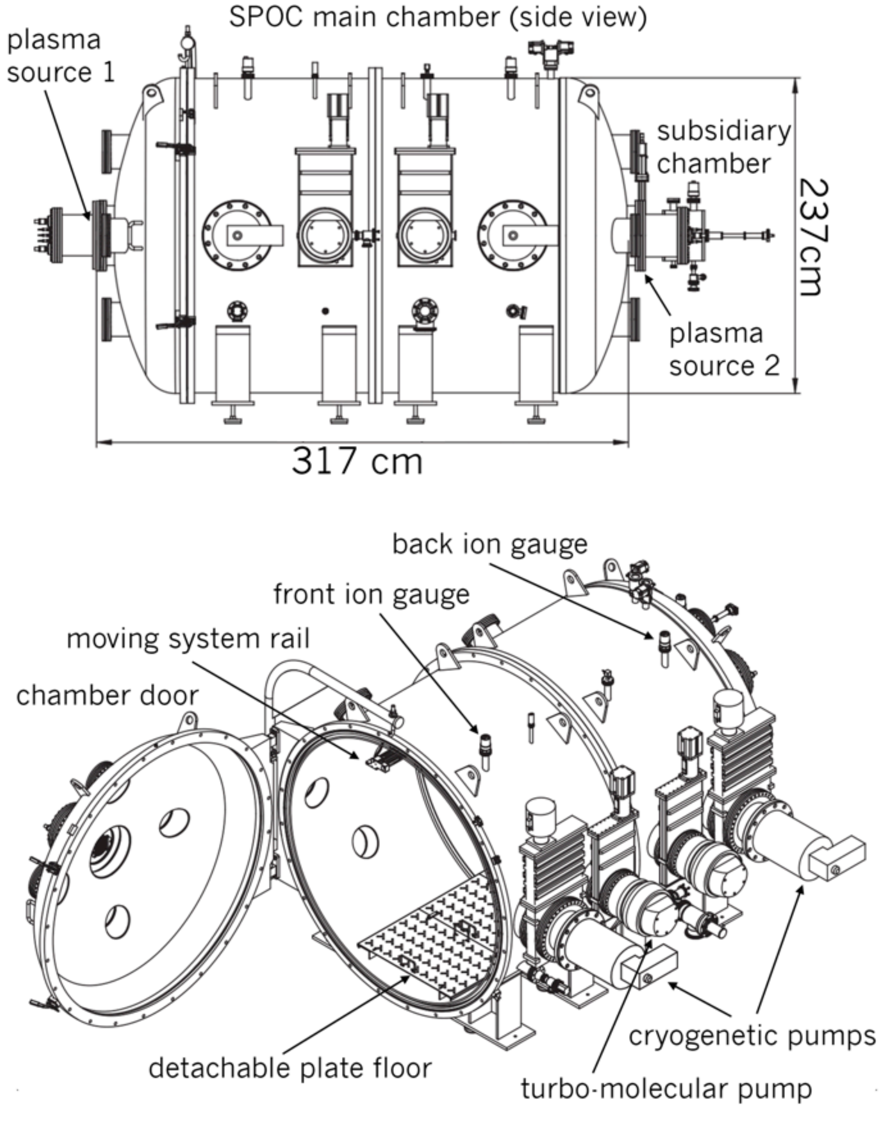

Fig. 1 The structure of SPOC. The right figure shows the side view of SPOC (the top view is shown in FIG. 3). The cylindrical chamber has the dimension of 3 m in length and 2 m in diameter. Two plasma sources are mounted at the center of the two chamber side doors. A subsidiary small chamber with a linear-motion feedthrough (the rod near the plasma source 2) is also attached on the door. The left figure shows SPOC with the door opened. With the pulley installed on the moving rail system, two-direction movements of sensor in SPOC can be done. The pressure in SPOC is monitored by a Pirani gauge and two ionization gauges mounted on the chamber top.is usually 10-15% lower than the back ionization gauge (IG2). The pressure values measured by the gauges are monitored in the SPOC control station. Pumps and valves are controlled

manually on the control station. A safety circuitry is programmed so that appropriate valves are automatically closed in case of unexpected pressure increase or vacuum failure.

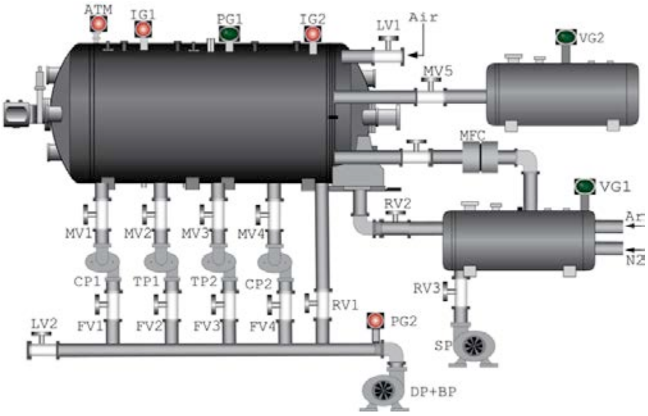

Fig. 2 The connection diagram of SPOC system. The abbreviation for each components are: ATM, sensor for atmosphere pressure; IG1~2, ion gauges; PG1~2, VG1~2, pirani gauges; LV1~2, leak valve for vacuum breaking; RV1~3, FV1~4, MV5, pneumatic valves; MV1~4, solenoid valves; CP1~2, cryogenic pumps; TP1, turbo-molecular pump; DP+BP, mechanical pump; MFC, flow control valve and flow meter.

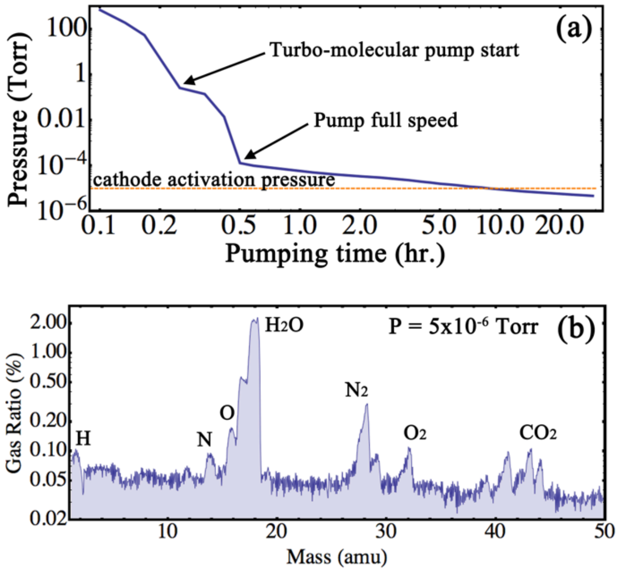

Fig. 3. (a) Chamber pressure monitored by the front ion gauge. This data is recorded after one week preparation of sounding rocket payload tests. Only the turbo-molecular pump and the mechanical pump are operating. The needed pressure for activation of the cathode of plasma sources can be achieved in half a day. (b) The neutral gas ratio measured by the residual gas analyzer (mass spectrometer) mounted on the chamber top. The gas in chamber is composed of molecules of the air. The water molecule is the dominant component. When the cryogenic pumps are turned on, these water molecules

will be pumped out in a short time and the chamber pressure drops one order further quickly.

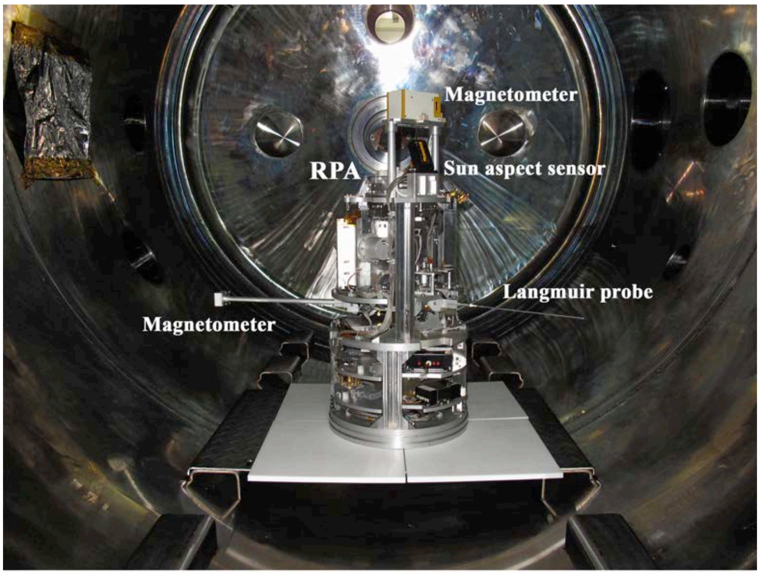

Fig. 4 Photo of the preparation of sounding rocket scientific payload performance tests. The instruments of Langmuir probe, retarding potential analyzer, neutral particle analyzer, fluxgate magnetometer, magneto-resistive magnetometer and sun aspect sensor are integrated and tested in both the vacuum and plasma environments in SPOC.

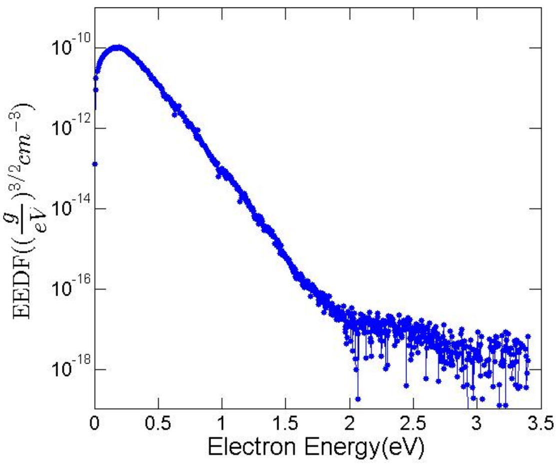

Fig. 5 Example of electron energy distribution function of SPOC plasma. The result was obtained by combining second harmonic method and electron channel multiplier. Please not that Vertical scale is almost 4 orders variation.