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Challenge to Erosion-less Hall Thruster
無損耗ホールスラスタへの挑戦

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In order to investigate the applicability of the magnetic shielding technique to thruster with anode layer (TAL), the guard-ring current of a TAL type thruster of UT-58 was measured. The magnetic shielding is the technique of reducing the channel wall erosion caused by ion sputtering by aligning the magnetic lines with the channel wall. The magnetic shielding has been applied to stationary plasma thruster (SPT), but it is unclear that this technique can be applied to TAL because the electric potential of channel wall is different between SPT and TAL. From the result, the guard-ring current of magnetic shielding configuration thruster was reduced. Therefore the feasibility of the magnetic shielding to TAL was confirmed.

1. Introduction

Hall thruster is considered to be suitable for in-space transportation of large mass structure such as Solar Power Satellite owing to its high thrust efficiency and less difficulty of increasing the size [1]. Because hall thruster need long operation period due to its small thrust for large mass transportation, the lifetime is one of the most important performances.

Lifetime of hall thruster mainly depends on the wall erosion caused by ion sputtering. In order to enhance the lifetime performance, the technique of magnetic shielding [2] was developed, and a SPT type thruster of BPT-4000 with magnetic shielding achieved a zero-erosion configuration [3]. The principle of the magnetic shielding for SPTs is shown in Fig. 1. The magnetic field lines of the unshielded thruster cross the channel walls as shown in Fig. 1 (left), while the magnetic field lines of the magnetically shielded thruster are parallel to the channel walls shown in Fig. 1 (right), which can be realized by modifying the geometric and

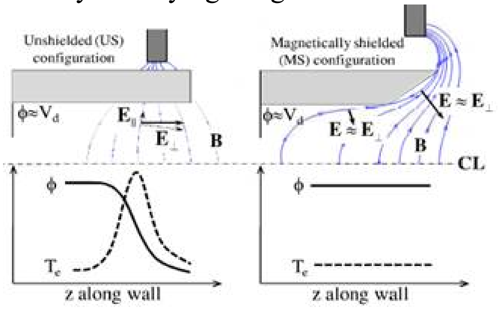

Fig. 1. The principle of the magnetic shielding, unshielded (left) and magnetically shielded (right)

magnetic configuration of the channel wall. Because the equipotential lines form along the magnetic field lines if the electron temperature along the magnetic field line is low, the parallel magnetic field lines near the channel walls cause the electric field which repels the ions from channel walls, resulting in the reduction of the channel wall erosion. However because the electric potential of TAL is different from that of SPT, it is unclear that magnetic shielding can be applied to TAL.

The objective of this paper is to investigate the applicability of the magnetic shielding technique to TAL to enhance the lifetime performance.

2. Experiment

2.1 Experimental setup

A TAL type thruster of UT-58 [4] developed at the University of Tokyo was used for the test of the magnetic shielding technique. A picture of UT-58 is shown in Fig. 2 (left) and the cross section drawing of UT-58 is shown in Fig. 2 (right). To install magnetic shielding for UT-58, the configuration of magnetic lines and channel wall was changed. By changing the width of magnetic pole piece, the different shape of magnetic line can be applied. In this research, UT-58 with unshielded and magnetic shielding was tested.　The lines of magnetic force and cross section schematics of unshielded and magnetic shielding are shown in Fig. 3 respectively. While there are lines of magnetic force which terminate the channel walls in the case of unshielded thruster, there are few lines which terminate the channel wall in the case of the magnetic shielding. In this research, the vacuum chamber with a diameter of 2.0 m and a length of 3.0 m was used. The diffusion pump (SPD-36 made by ULVAC Co., pumping speed is 37000 L/s) was used to evacuate the chamber. The corrected pressure with thruster operation with xenon propellant of 2.0 Aeq (2.72 mg/s) was 4.6×10^{-5} Torr.

2.2 Experimental method

To evaluate the channel wall loss, the guard-ring current was measured to obtain the ratio of ion loss current and the discharge current $\varepsilon_{\text{ion-wall}}$, which is defined by Eq. (1),

$$\varepsilon_{\text{ion-wall}} \equiv \frac{I_g}{I_d} = \frac{I_g}{I_b + I_e + I_g} \tag{1}$$

where I_g is guard-ring current and I_d is discharge current. During the guard-ring current measurement the front surface of the thruster was covered with boron nitride (BN) powder to prevent ions from

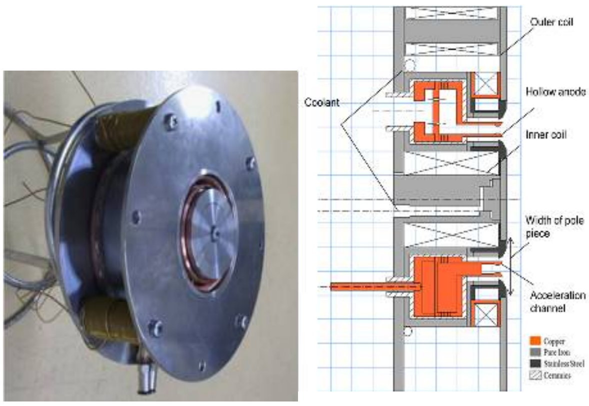

Fig.2. UT-58 thruster of a picture of UT-58 (left) and the cross section drawing (right)

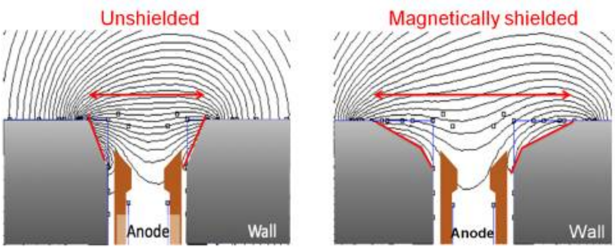

Fig. 3. The geometric and magnetic configuration of UT-58 with the width of 14 (left) and 24 (right)

Fig. 4. Picture of the thruster surface covered by boron nitride (BN) powder

the front surface of the thruster was covered with boron nitride (BN) powder to prevent ions from going into the thruster from the front surface as shown in Fig. 4. Insulating surface blocks the current of the charge exchange (CEX) ions, which increases a guard-ring current.

3. Results and discussion

The channel wall loss of UT-58 with the unshielded and magnetic shielding was measured. The operation condition with the unshielded and magnetically shielded was the same: the discharge voltage of 200 V, the xenon mass flow rate of 2.0 Aeq (2.72 mg/s).

The $\varepsilon_{\text{ion-wall}}$ of the magnetic shielding thruster was 3.7% while the $\varepsilon_{\text{ion-wall}}$ of the unshielded thruster was 7.1%. This result shows that ion loss toward the wall with the magnetic shielding thruster is small compared with the unshielded thruster. Therefore the channel wall erosion of UT-58 with magnetic shielding can be inferred to be reduced because of the installation of geometric and magnetic configuration of the channel wall of magnetic shielding.

Table I. Summary of guard-ring current measurement (the discharge voltage of 200 V, the xenon mass flow rate of 2.0 Aeq (2.72 mg/s))

	I_d [A]	I_g [A]	$\varepsilon_{\text{ion-wall}}$ [%]
Unshielded	2.68	0.19	7.1
Magnetically shielded	2.70	0.10	3.7

4. Conclusions

In order to investigate the applicability of the magnetic shielding technique to TAL, the guard-ring current measurement was conducted with unshielded and magnetically shielded TAL thruster of UT-58. From the result, the channel wall erosion rate of UT-58 with magnetic shielding is lower than that of UT-58 without the configuration of magnetic lines and channel wall of the magnetic shielding. Therefore a magnetic shielding is applicable to TAL based on this result.

References

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