【Grant-in-Aid for Scientific Research (S)】

**Broad Section C**

**Title of Project：** **Research and Demonstration of Next Generation Hall Thrusters and their Mechanism for Producing High-speed Plasma Jet**

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## 【Purpose and Background of the Research】

Orbital transfer capability of a spacecraft is usually limited by the amount of available velocity increment (ΔV), and higher values of ΔV are possible by increasing the velocity of a jet released from a spacecraft. In fact, increasing the jet velocity is the main topic in the research of spacecraft propulsion, and even small amount of velocity increment is considered significant because the velocity increase can improve the performance of a spacecraft. In this study, Hall thruster is dealt with. Commonly known feature of Hall thruster is a moderate jet velocity from 15 to 30 km/s and it is obtained by using electrostatic acceleration in an annular channel. Although this velocity range is suitable for Earth-orbiting missions, drastic improvement is preferred for interplanetary missions. The Hall thruster in this study is then targeting at velocities from 40 km/s up to 50 km/s which are necessary for Mars round-trip missions or explorations in the outer solar system. For this purpose, high discharge voltages as well as high magnetic fields in comparison with conventional Hall thrusters are used to optimize the design of plasma production and acceleration processes. It is possible that ions are heated up at high discharge voltages as a result of turbulent flow; in this case, the maximum velocity of a jet will be restricted. This study is, however, intended to overcome such difficulty by clarifying the background physics and by suppressing unstable effects.

## 【Research Methods】

Experimental study is to be conducted to evaluate the target jet velocity along with its plume characteristics. The target velocities to be demonstrated are plotted in Fig.1, in which 40-50 km/s range is highlighted. This regime is clearly distinguished from the previous studies at 30 km/s or lower velocities. Plan for this study is divided into three steps: 1) initial phase where the first very high voltage Hall thruster is tested; 2) optimization phase where various acceleration channel and cathode configurations are compared to find the best one, and 3) final phase where a system-level evaluation is conducted and application to deep space missions is proposed.

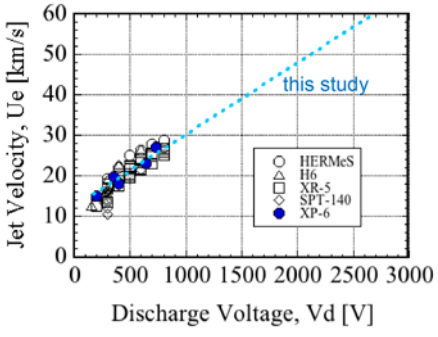


Figure 1 Regime of Hall thruster in this study.

During the first phase, first laboratory model is designed and tested to experimentally demonstrate a Hall thruster at 40 km/s or higher velocity. After that, in the second phase, optimization process follows. If velocity limitation is found during this process, physical explanation is pursuit and corresponding thruster lifetime limitation is considered. Reflecting these results, a prototype model is designed to evaluate system-level feature. Finally, a mission proposal is released to show next generation solar system exploration using the new thruster system.

## 【Expected Research Achievements and Scientific Significance】

Although the usage of electric propulsion is increasing in the world, there are some limitations in the current technologies for ion thrusters and Hall thrusters. That is, these thrusters can obtain either high velocity or high density, but both of these cannot be obtained simultaneously. This study tries to obtain both highly velocity and high density by exploiting Hall thruster's new regime. With the new thruster, various space exploration that were not possible in the past became realistic to reach unknown part of our solar system.

## 【Publications Relevant to the Project】

- I. Funaki, et al., Development of a 6-kW-class Hall Thruster for Geostationary and Interplanetary Missions, Acta Astronautica, 170 (2020) pp.163-171.
- I. Funaki, et al., 1,000-hours Demonstration of a 6-kW Class Hall thruster for All-Electric Propulsion Satellite, Aerospace Technology Japan, 17 (2019) pp.589-595.

**【Term of Project】** FY2020-2024

**【Budget Allocation】** 146,500 Thousand Yen

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