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学位論文題名	Study on Green Monopropellant Propulsion with Discharge Plasma System （邦題：放電プラズマシステムを用いた低毒性一液式宇宙推進機に関する研究）
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【論文の内容の要旨】

（ 学位論文要旨 ）Green monopropellants for space propulsion system of spacecraft have been continuously developed and researched in the world. Replacements of conventionally used hydrazine have been called green monopropellant because they have lower toxicities than hydrazine. In Japan, one green monopropellant, called hydroxylammonium-nitrate (HAN) based monopropellant SHP163 (is a liquid mixture of HAN/ammonium nitrate/water/methanol in a ratio of 73.6/3.9/6.2/16.3 by weight percentages), has been developed by ISAS/JAXA. This monopropellant is thus storable as a liquid under a vacuum condition and has higher density specific impulse than hydrazine. Additionally, the mass of a propulsion system can be reduced while maintaining the same delta-V. However, when employing HAN based monopropellants in a conventional solid catalyst thruster, there are technical problems in environments with higher operating

temperatures and atmospheric oxidation such that the catalyst sinters, reduces, and then deactivates. To solve these problems, this research is an effort to develop a HAN-based monopropellant thruster with an alternative ignition system that uses discharge plasma. In this discharge plasma system, an intense electric field forms between the electrodes of hollow cylindrical geometry using a direct current power supply, the discharge plasma is then generated from ionized gas, and the monopropellant is ignited when it comes into contact with the discharge plasma. The objective of this study is to design and build the laboratory model thruster with discharge plasma system for the HAN-based monopropellant SHP163, and to evaluate the performance characteristics of the thruster under vacuum condition. Additionally, the target thrust-level is from 0.10 N to 1.0 N for reaction control system thruster.

The outline of thesis is organized as follows. Chapter 1 presents the development status of green

monopropellant thruster in the world, the technical problems of green monopropellant thruster, and the objectives of this study. Chapter 2 provides the overview of discharge plasma system, and the concept of chemical reaction by discharge plasma. Chapter 3 presents the schematic of experimental apparatus and the specifications of measurements. Chapter 4 presents the results of propellant ignition tests, the effects evaluations of gas injection methods on generated plasma conditions and SHP163 ignition characteristics, and proposes the discharge plasma system. To evaluate the SHP163 ignition characteristics of discharge plasma system, the effects of geometric swirl number on the ignition characteristics were evaluated under atmospheric conditions. It is concluded that the geometric swirl number has strong effects on the plasma distribution, the propellant ignition probability, and the ignition delay time. The continuity of the exhaust flame from downstream of the discharge plasma system with a geometric swirl number of 6.7, and the conditions of combustion stability was confirmed at sea-level. Chapter 5 presents the experimental results of vacuum firing tests to design and build a thruster with discharge plasma system. In terms of both propellant injector and combustion chamber, the thruster design is estimated. As a result, it was observed that a shorter L-star increased the characteristic exhaust velocity efficiency (i.e. reactivity). Additionally, for all SHP163 feed pressure (i.e. SHP163 mass flow rate of 1N-class), there were no failed ignition cases with a single-hole injector. It was found from the result that a maximum thrust of 0.37 N at nozzle expansion ratio of 1 was achieved with power consumption of 527 W and an SHP163 mass flow rate of 0.34 g/s, in conjunction with characteristic exhaust velocity (C-star) efficiency of 98%. In this experiment, it was obtained the consumed power at combustion of SHP163 for 15 s was similar to preheating energy of catalyst, and the hot firing tests of the thruster was demonstrated the operation successfully under vacuum condition. Chapter 6 shows the thruster performances that are evaluated by the characteristics exhaust velocity efficiency and the emission spectra. As a result, at the feed pressure of 0.6 MPa, a maximum thrust of 0.50 N was achieved with power consumption of 564 W and SHP163 mass flow rate of 0.31 g/s. In addition, it was confirmed that measured thrust was varied from 0.25 N to 0.50 N in a range of SHP163 mass flow rate from 0.09 g/s to 0.31 g/s. Here, at these experiments, the mass flow rate of argon gas is set at 0.15 g/s for plasma generation. Furthermore, in terms of the combustion products of SHP163, the emission spectrums of carbon monoxide, swan band, hydroxyl radical, hydrogen atom, and oxygen atom were observed under vacuum condition. It was confirmed that the characteristic exhaust velocity efficiency tends to be higher at higher spectral intensity. Moreover, as a result of thruster lifetime-evaluation, at an accumulated firing time of 1646 s, no effect of electrode degradation on the performance of the thruster was observed. Finally, Chapter 7 summarizes this thesis. Since this study, the green monopropellant propulsion with discharge plasma system has been proposed, evaluated the performance, and demonstrated under vacuum condition.