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Measurement of thrust induced by a water-fueled magnetron sputtering source

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Owing to a small satellite represented by CubeSat, space missions are no longer restricted to large companies and national space agencies; the number of CubeSats to be launched are expected to increase hereafter for scientific research and industry [1]. For sustainable space development with the small satellites, compact electric propulsion devices that satisfy the requirements for size, weight, specific impulse, thrust-to-power ratio, and so on, are required. A neutralizer is often installed on conventional electric propulsion (EP) devices, e.g., gridded ion and Hall thrusters. Measurement of the thrust with a dc magnetron sputtering source has been demonstrated in recent years [2] and the reduction of the thrust-to-power ratio is detected for the highly ionized discharge, i.e., a high-power impulse magnetron mode [3]. These results implies that the sputtered and electrically neutral particles ejected from the system are responsible for the thrust generation. Therefore, the sputtering source has been proposed to be applicable to a neutralizer-free electric propulsion device. In the previous experiments, argon gas is used for the discharge propellant as well as the conventional EP devices. The high-pressure gas tank and the regulator limit the reduction of the size and the weight, which would be serious technical problems for the small satellites. To solve this problem, solid and liquid propellants such as water or Iodine are alternative candidates [4,5].

In the present study, the thrust generation by ejection of neutral atoms from a magnetron sputtering source is demonstrated, where liquid water is selected as a fuel for the discharge because of its safety, cost, and existence of the resources in space environment [6].

Figure 1 shows the schematic diagram of the magnetron sputtering source attached to a 260-mm-diameter and 732-mm-long vacuum chamber evacuated by a turbomolecular pump [2]. A radial magnetic field of about 500 Gauss is formed near the target surface by locating two annular permanent magnets behind the copper target. Gaseous water is introduced from the backside of the sources. Liquid water in the tank changes into gaseous one at low pressure and fed into the magnetron sputtering source. A mass flow controller that can be operated at small differential pressure is used to control the mass flow rate of the gaseous water. A target plate attached to a pendulum structure and a LED displacement sensor are installed in the chamber for the thrust measurement. The absolute value of the thrust corresponds to the force exerted to the pendulum target [7], which can be obtained from the measured displacement and a calibration coefficient.

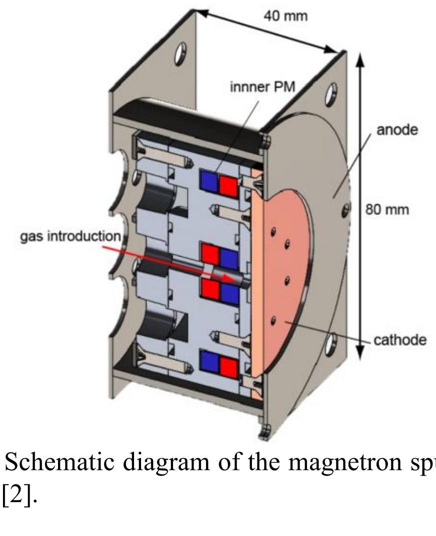

Fig. 1. Schematic diagram of the magnetron sputtering source [2].

By applying a dc voltage ranging from 550-1000 V between the anode and the cathode through a resistor of 1 kΩ, the donut shape plasma is created due to the **E**×**B** drift near the cathode target surface. The generation of water plasma by magnetron sputtering source is confirmed by an optical emission spectroscopy measurement, where the similar emission spectrum to other water-fueled plasma source has been detected [8]. When the plasma is ignited, the displacement of target pendulum is clearly detected.

The maximum thrust of 200-400 μN, the thrust-to-power ratio of about 3-4 mN/kW, and the specific impulse of 150-350 s are obtained in the water-fueled magnetron sputtering source. The detailed results including the discharge characteristics and discussion will be shown in the presentation.

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