Solar Thermal Propulsion System for Microsatellites

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Abstract

This paper shows an application of single crystal metals and Single Shell Polymer Concentrator (SSPC) to Solar Thermal Propulsion (STP). Based on it, we fabricated a breadboard model of STP system (STP-BBM) for microsatellites. We also proposed Eco-Friendly End-of-Life De-Orbiting (EFELDO) by using such a high performance STP system.

Introduction

This paper shows an application of single crystal metals and Single Shell Polymer Concentrator (SSPC) to Solar Thermal Propulsion (STP). The Advanced Space Technology Research Group (ASTRG) in the Japan Aerospace Exploration Agency (JAXA) has been devoting itself to investigate and develop the STP as one of the most promising propulsion for an Orbit Transfer Vehicle (OTV). STP is one of the thermal propulsion utilizing concentrated solar rays, and has high specific impulse (800-1,000 sec) in an appropriate thrust magnitude range (10mN-10N) so that it can be a strong candidate for future OTVs. There are two important keys to study STP, the one is to develop a STP thruster with no recrystallization embrittlement, the other is to manufacture an ultra-light solar concentrator.

Thruster

As far as the STP thruster concerned, the National Institute of Materials Science (NIMS) patented single crystal refractory metals and we applied them to make and fabricate portions to the STP thruster (Fig. 1). In order to reinforce and seal joints of the portions, the STP thruster was deposited with W-CVD coating because tungsten has lower vaporizing pressure than the other refractory metals. The STP thrusters of from 6 mm to 65 mm in outer diameters were fabricated. By combining with the most suitable concentrators to the respective STP thrusters, the STP thrusters except the 6mm-diameter-thruster attained over 2,000 K of thruster and propellant temperatures on ground tests, which is corresponding to 800 seconds of specific impulse in using hydrogen as a propellant. The target temperature of the 6mm-diameter-thruster made of single crystal molybdenum is 1,500 K of gas propellant, corresponding to 600 seconds of Isp in using hydrogen as a propellant.

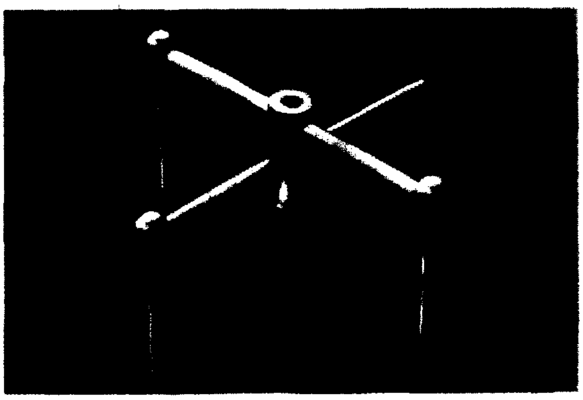

Fig. 1 STP thruster

Single Shell Polymer Concentrator

Concerning to the solar concentrator, we had manufactured a conventional coaxial type SSPC of 220, 430, and 600 mm in diameters by using a highly precise paraboloidal glass mirror as a mold by means of Straight Forming Method of a sheet of aluminized or silvered polymer films (Fig. 2). Its area density is only 180 g/m2 even in the case of 127-micron-thickness film. However, such a conventional SSPC includes forming error due to inevitable elastic deformation of residual stress and/or thermal expansion of the film in manufacturing, and has a quite larger solar focal image than expected. Although over 5,000 of concentration ratio is required to a solar concentrator for STP, the concentration ratio of the conventional SSPC was only 3,000 at the highest. Accordingly, an improvement of the mold by taking the forming error into consideration was indispensable. With the improved mold designed to manufacture a coaxial SSPC of 400 mm in diameter and 196 mm in focal length, the improved SSPC was formed of highly precise paraboloidal shape and 6,700 of concentration ratio was obtained with it (Fig. 3). The improved SSPC is the most suitable to the 6mm-diameter-thruster. As well as the coaxial SSPC, an off-axis type SSPC of 500 mm in effective diameter and 282 mm in focal length was also improved. Furthermore, we proposed a gossamer type SSPC to compensate vulnerability of it, which has cobweb-like grooves for reinforcement to increase its buckling strength.

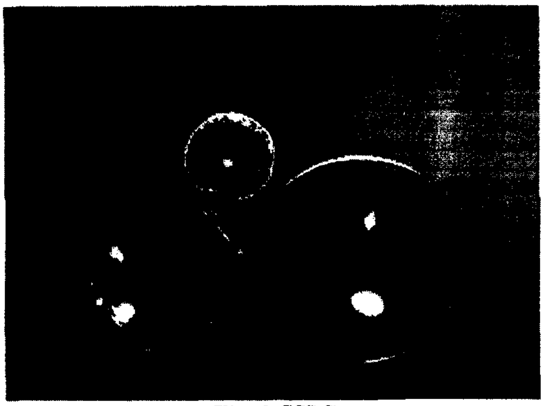

Fig. 2 SSPC

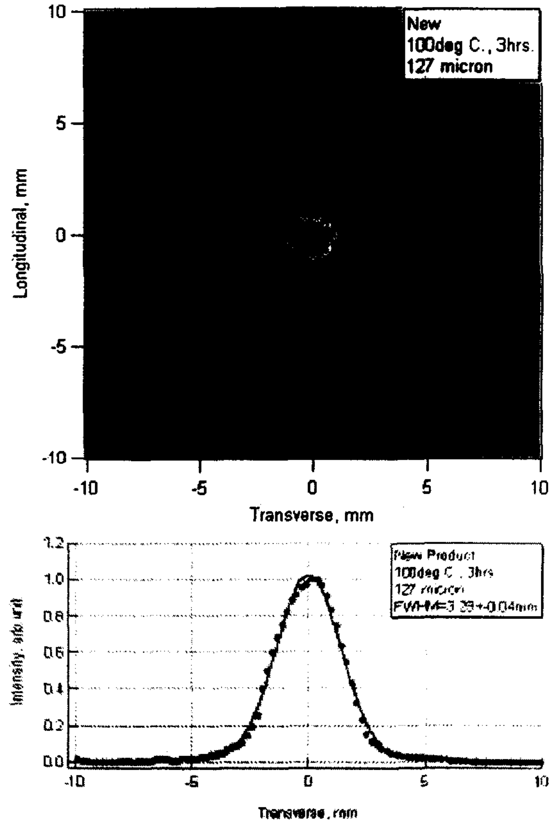

Fig. 3 Solar concentration test result of the improved SSPC

STP system for microsatellites

Based on the above, we fabricated a breadboard model of STP system (STP-BBM) for microsatellites (Fig. 4). We also proposed Eco-Friendly End-of-Life De-Orbiting (EFELDO) by using such a high performance STP system. It contains the 6mm-diameter-thruster and the improved SSPC. We conducted solar heating test in the atmosphere and the thruster temperature reached over 1,300 K (Fig. 5). It suggests that the target temperature 1,500 K is validly attainable in space. Now is under designing of Post BBM.

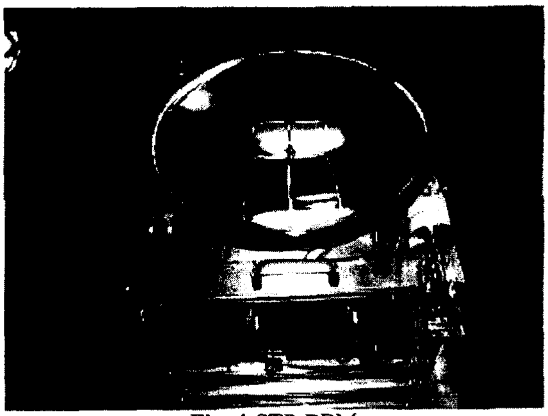

Fig. 4 STP-BBM

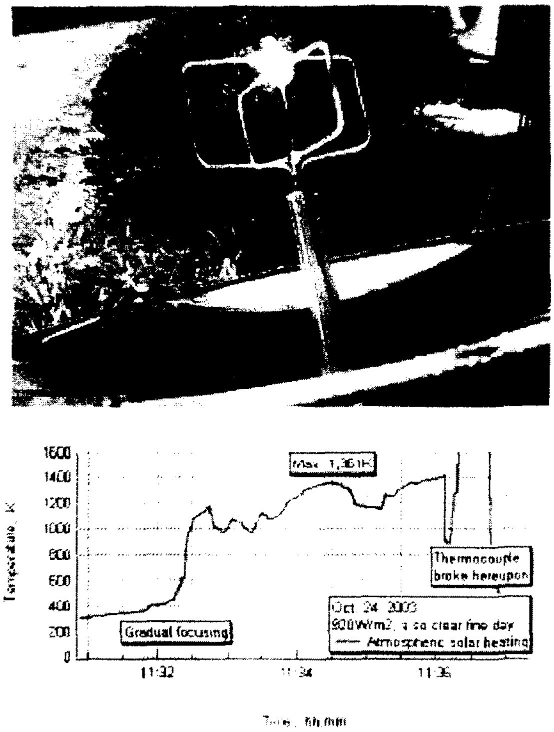

Fig. 5 Atmospheric solar heating test of the STP-BBM

Conclusion

We had already obtained manufacturing techniques of the single crystal molybdenum thruster and the improved single shell polymer concentrator, and fabricated the STP-BBM with them. As the result of atmospheric solar heating test, the target temperature of the thruster in the STP-BBM, 1,500 K, is validly attainable in space. Now is under designing of Post BBM.

References

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