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Micro plasma thruster for small spacecraft

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A microplasma thruster of electrothermal type has been proposed using azimuthally symmetric microwave-excited plasmas, which consists of a microplasma source and a micronozzle. The microplasma source is made of a dielectric chamber 2 mm in inner diameter and 10 mm long covered with a metal grounded, producing high temperature plasmas at around atmospheric pressures. The micronozzle has a throat 0.2 mm in diameter, converting high thermal energy of plasmas into directional kinetic energy of supersonic plasma flows. First, we have developed a numerical model for microwave-excited microplasmas in Ar and plasma flows in the micronozzle. The model consists of three modules: a volume-averaged global model and an electromagnetic model for microplasma sources, and a two-temperature fluid model for micronozzle flows. Numerical results indicated that the microwave power absorbed in plasmas increases with increasing microwave frequency f and relative permittivity ε_d of dielectrics, and that a certain combination of frequency and permittivity significantly increases the power absorption. The micronozzle flow was found to be heavily affected by viscous dissipation in thick boundary layers, indicating that shortening the nozzle length with increasing half-cone angles suppresses the effects of viscous loss and thus enhances the thrust performances. A thrust of 2.5-3.5 mN and a specific impulse of 130-180 s were obtained for a given microwave power range (P_t <10 W), which is applicable to a station-keeping maneuver for microspacecraft less than 10 kg. Moreover, we have developed a microwave-excited microplasma source, based on the model analysis, with mullite ($\varepsilon_d \approx$6) and zirconia ($\varepsilon_d \approx$12-25) being employed for dielectrics. Experiments were performed at f=2 and 4 GHz,P_t <10 W, Ar flow rate of 50 sccm, and microplasma chamber pressure of 10 kPa. Optical emission spectroscopy and Langmuir probe measurement were employed for diagnostics of microplasmas, indicating that the ArI emission intensity and plasma density n_e increase with increasing f and ε_d, and that the n_e is in the range $10^{12}-10^{13}$ cm^{-3}. Moreover, the rotational temperature T_{rot} of N_2 added was in the range 1100-1500 K, and the specific impulse estimated was about 70s.