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Parametrical optimization of inductively coupled RF ion thruster design

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Nowadays, the popularity of the plasma thrusters, which has a simple and compact design, is increasing in-space applications. The inductively coupled radio frequency (RF) ion thrusters (ICP-RITs) are mostly preferred due to supplying high specific impulse and high efficiency. The ICP-RITs are composed of five main parts; discharge vessel, RF coils (RFC), RF generator with its matching network system (RFG), ion optics system (IOS-screen grid, accelerator grid and decelerator grid) and a neutralizer. To understand the physical working principles of these devices, it is necessary to solve the electromagnetic (EM) field equations, which are based on the Maxwell`s equations. Therefore, in this study, we used the COMSOL Multiphysics® software program for the numerical analysis of the ICP-RITs. Firstly, we investigated the locational (along the axial direction of the discharge vessel-at the center and on the upper part that is close to the ion extraction unit) effects of the RF coils on the generated plasma parameters (ne and Te) at 30 mTorr-300 Watt as shown in Figure 2. The coils shown in Figure 1 provide 10 times more ni and 2.6 times more at the screen grid. These parametrical analyses can be clearly observed in the Figure 2-b. For this reason, the following studies were based on this configuration. Then, we tried to understand the effects of the aspect ratio (AR=L-length/D-diameter=2, 3, 4, 5 and 6) and the gas pressure (30-230 mTorr) on the plasma parameters, ion density and electron temperature for the fixed RF power (300 Watt). In Figure 3-a, the density belongs to the ions that are extracted from the screen grid. The location of the screen grid can be seen from the Figure-1. As clearly seen from the Figure 3-a, the ion density increases logarithmically with the gas pressure and the aspect ratio. The reason of this increase due to the pressure is the ideal gas law. From the Figure 3-b, all the electron temperature variations are overlap. However, a closer view to the graph shows that the variations are slightly different from each other with respect to the aspect ratio value. Also, a temperature exponential decrement with the gas pressure is clearly observed from the figüre. Because the number of the Ar gas particle increases with increasing gas pressure. However, at constant RF power, the average electron thermal energy decreases that means the thermal kinetic energy per charge also decreases. In conclusion, the main goal of this work is attracting more ions from the RF ion thruster. To achieve this goal, we will design our thruster according to the dimensions recorded at AR=6 and also we will set the gas pressure at 230 mTorr.

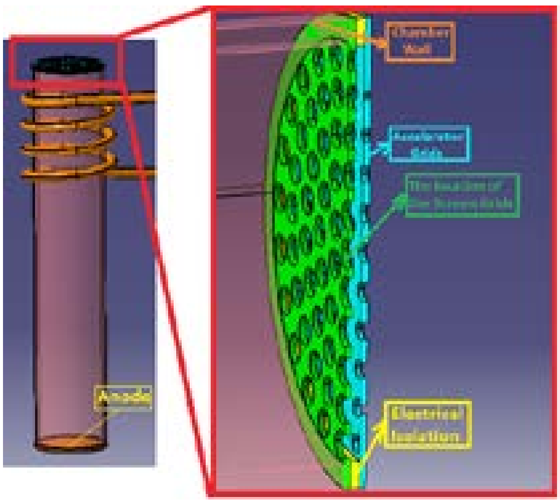

Figure 1: The thruster geometry: Plasma chamber, RF coils, anode and the ion extraction unit: screen and accelerator grids.

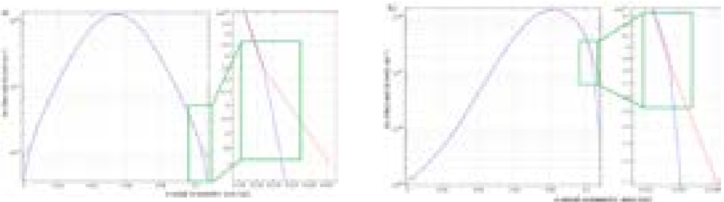

Figure 1: The n_e and n_i evolutions along the z-axis where the coils are located a) at the center and b) on the upper.

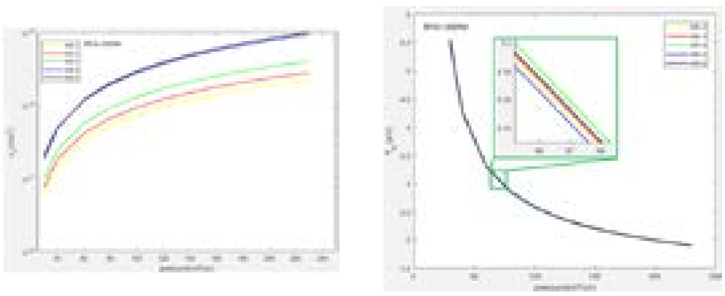

Figure 2: The gas pressure and the aspect ratio dependence of a) the n_i and b) T_e at 300 Watt.

Recent Publications:

1. Dobkevicius M and Feili D (2017) Multiphysics model for radio-frequency gridded ion thruster performance. Journal of Propulsion and Power 33:939–953.
2. Turkoz E and Celik M (2014) 2D Electromagnetic and fluid models for inductively coupled plasma for RF ion thruster performance evaluation. IEEE Transactions on Plasma Science 42:235–40.
3. Chabert P, Monreal J A, Bredin J, Popelier L and Aanesland A (2012) Global model of a gridded-ion thruster powered by a radiofrequency inductive coil. Physics of Plasmas 19:1–8.
4. Browning J, Lee C, Plumlee D, Shawver S, Loo S, et al. (2011) A miniature inductively coupled plasma source for ion thrusters. IEEE Transaction on Plasma Science 39:3187–3195.
5. Goebel D (2008) Analytical discharge model for RF ion thrusters. IEEE Transactions on Plasma Science 36:2111–2121.

Biography

Ümmügül Erözbek Güngör has been working as a Research Assistant in the Physics Department at Middle East Technical University (METU) since 2012. She has a BS and an MS Degree in Physics and is a Physics Teacher at the METU. She also holds a PhD in Physics. She has recently been working on plasma Spectroscopy, Plasma Diagnostics and Plasma Modeling.

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